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TNO report

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Primary exposure assessment for workers involved in insect / cricket breeding

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1 Introduction

1.1 Flying Food

The Flying Food initiative creates employment and access to affordable proteins by setting up a new, inclusive value chain of crickets for human consumption in Africa. Over the last 5 years, the Flying Food project successfully established rearing, processing and retailing of crickets in Kenya and Uganda through an international public private partnership led by the Dutch innovation institute TNO. The Flying Food consortium includes 4 Dutch partners: Protifarm Ltd, New Generation Nutrition Ltd, Wageningen Food and Biobased Research and TNO.

Currently 450 smallholder farmers, including 80+ women, actively rear crickets, with 200 additional farmers preparing to start. Two middle-scale companies have been established with the combined potential to deliver 50 tons of crickets per annum. Three processing companies dry, grind and package the crickets and deliver them to a total of 10 market outlets as snacks or powder. Fresh crickets are used in cricket samosas and as powder in fortified porridge and cookies. At full capacity, the existing supply chain could deliver 5.000.000 servings per annum. Because the demand outpaces supply, the Flying Food initiative has the ambition to scale up in existing countries and also to eight other countries in Sub-Saharan Africa.

Before scaling up we want to have more insights in the potential health risks of workers in insect breeding. In the Netherlands there are several mainly large scale companies active in insect breeding and there are signs that the cricket dust may cause occupational allergic disorders. In this report we describe the results of a literature review on this topic and also list measures to safeguard the health of workers.

1.2 Small scale cricket farms in Africa

Small holder farmers in Kenya and Uganda within Flying Food make use of the following breeding system:

- Crickets are farmed indoors to protect them from predators and to keep them warm. Crickets grow best with a constant temperature of 28-32 °C (day and night);
- Farmers build a separate insulated farm of 6 m^2 (2 x 3 meters), coincidentally breed the crickets in their homes;
- They breed the crickets in crates – size 40 x 60 x 22 cm – with 2 ventilation holes, covered with stainless steel gauze;
- Each farmer uses 30 crates – 6 columns of 5 stacked crates. Only the top crate has a lid, for the other crates bottom of the crate above is used as a lid;
- Each crate contains 2500 crickets, having a weight of around 1 kg when ready to harvest. Number is depending of proper organization, temperature, feed and substrate egg boxes. Eggs are placed in a tray with substrate in a crate. This crate is completely closed (no ventilation holes), so it stays warm and humid. As soon as the crickets hatch (no larval stage) they start to move around, and then

fall out of the tray. Every three days, these tiny crickets are put in a separate container, in which they stay until harvesting. Crickets molt 8 times before they reach adulthood. The crickets are harvested after the 7th molt, this is around 8-12 weeks;

- 1 or 2 people take care of the crickets, they spend 1 to 2 hours a day on feeding and watering the crickets, harvesting and cleaning crates;
- Crates are cleaned daily or weekly (dependent air humidity) by pulling the crate a bit forward to create a small opening. The bowls of food and water are taken out, the hiding places (egg trays) are held up by hand while the other hand is scraping / sweeping at the bottom with a ruler, after which the poo and exoskeletons are scooped out;
- Harvesting is done inside the farm by placing the crate on its side in a large bucket. Then the hiding materials are shaken / tapped empty and removed from the crate. Then the crickets are pushed out of the crate into the bucket. Most of the dirt remains in the crate. Then the crate is removed from the bucket, and the crickets are removed from the bucket with a sieve or put in a net by hand to ensure that they no longer have any dirt with them. These crickets are then collected the same day for processing elsewhere (transported on (dry) ice) (for food safety reasons);
- If the crickets are used for personal consumption, they are blanched as soon as possible (in the net or sieve), after which they are usually dried;
- After harvesting the crates are cleaned well before they are used again. Most of the dirt is first tipped / shaken. The crates are cleaned outdoors by hand with water (in a bucket) and maybe some soap and a cloth. Then the crates are immersed in a bath of bleach, in order to kill bacteria and dried outdoors in the sun;
- The dirt that comes out of the crates (feces + exoskeletons) is often used as fertilizer, so it is likely to be stored somewhere before it is used;
- Before working with the crickets you should at least wash your hands with soap.

1.3 Medium scale cricket farms in Africa

Medium scale farmers within Flying Food in Kenya and Uganda make use of the following breeding system:

› Crickets are farmed indoors to protect them for predators and to keep them warm. Crickets grow best with a constant temperature of 28-32° C (day and night);
› Farmers build a separate farm of 70 m^2, with insulated walls and roof;
› They breed the crickets in crates – size of 40 x 60 x 22 cm – with 2 ventilation holes, covered with stainless steel gauze;
› The farm has 6 main rooms:
  - Hatchery: 13-15 low crates with size of 40 x 60 x 11 cm, with parent stock laying eggs;
  - Breeding space: 485 crates to upbreed the crickets – size 40 x 60 x 22 cm;
  - Harvesting: inside or outside – emptying crates;
  - Cleaning room: inside or outside cleaning crates with water;
  - Processing room: cooking equipment for blanching room;
  - Dressing and wash room;
› Each farmer uses 500 crates – stacked, vertical farming;
› Each crate contains 2500 crickets having a weight of around 1 kg when ready to harvest. Number is depending of proper organization, temperature, feed and substrate egg boxes. Crickets molt 8 times before they reach adulthood. The crickets are harvested after the 7th molt, this is around 8 weeks (in case the temperature is between 28-32°C during day and night);
› Six people take care of the crickets, they spend 8 hours a day on feeding and watering the crickets, harvesting and cleaning crates;
› Harvesting is done by removing the hiding materials, smoothly shaking/ tapping the crickets off. Then the crate is tipped empty on a multi-layer scaffolding, whereby the crickets remain on a grid and the dirt is collected one level below that grid. The crickets are put in a net / bag to blanch (and then dry or freeze) or are frozen immediately;
› After harvesting the crates are cleaned well before they are used again. Most of the dirt is first tipped / shaken. Then the crates are cleaned outdoors by hand with water (in a bucket) and maybe some soap. Then the crates are immersed in a bath of bleach, in order to kill bacteria and dried outdoors in the sun;
› Crates are not cleaned during their cycle, so feces and exoskeletons remain in the crate for the full 8 weeks;
› The dirt that comes out of the crates (feces + exoskeletons) is often used as fertilizer, so it is likely to be stored somewhere before it is used;
› Before working with the crickets you should at least wash your hands with soap.

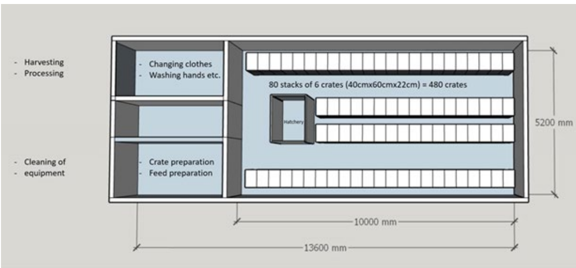

Illustration of medium scale cricket farm – breeding with 500 crates

2 Reported health effects in insect/cricket breeding

2.1 General information allergens (based on report Gezondheidsraad, 2009)

Occupational allergic disorders are commonly reported illnesses arising from exposure to allergens. Allergy is a hypersensitivity reaction that is initiated by a specific immune response to a foreign agent, an allergen, at an exposure level that is normally tolerated. One of its characteristics is increased sensitivity of the immune system (sensitization), induced by earlier exposure. Several instances of exposure may be required before evidence of allergic sensitization is seen, ultimately leading to allergic respiratory symptoms (i.e., allergic rhinitis, rhinoconjunctivitis, and asthma). Respiratory allergic symptoms may be mild to begin with, but become more serious as exposure continues, and may become irreversible. The Dutch Health Council makes the precautionary assumption that, in the event of continued exposure, almost all sensitized workers will ultimately develop allergic respiratory disorders. However, the risk on sensitization differs among individuals, and genetic predisposition probably plays a role in that.

However, the sooner diagnosis is made after the appearance of symptoms, and the sooner exposure is ended, the better the prognosis is. The long-term avoidance of exposure can even lead to the disappearance of detectable sensitization. However, in most cases, once a person has been sensitized, he or she will remain hypersensitive for the rest of his or her life and liable to develop the same allergic respiratory symptoms in the event of renewed exposure to the relevant allergen. No curative treatment is currently available to reverse this hypersensitivity.

There is a great variety of compounds, which cause respiratory allergic disorders in the workplace. They are divided into those with a high molecular weight (HMW) and those with a low molecular weight (LMW). The first group consists mainly of proteins, the second group consists mainly of small compounds. Cricket allergens are considered HMW allergens.

Exposure to an allergen is the key event in the development of an occupational respiratory allergy. The circumstances of exposure also may vary enormously. However, various other factors may also influence the development of such an allergy. These include exposure conditions, exposure pattern and simultaneous exposure to other substances. Furthermore, personal factors, such as genetic predisposition, lifestyle, infections, and the fact that exposure outside the workplace may have occurred earlier, can increase the risk for developing an allergy. In practice, it is difficult to quantify the significance of these risk factors for the development of occupational respiratory allergies, simply because not enough is yet known.

Apart from deriving of occupational exposure limits to protect workers' health (which is assumed not likely to be the case in Africa), it should be taken into account that cases of allergic sensitization and respiratory disorder can always happen. Therefore the early detection of sensitized workers, by means of periodic screening, can be a potentially valuable tool. However, periodic screening is of value only where accurate and reliable tests are available for the detection of allergic sensitization to the relevant allergen at an acceptable price. If immunological tests are not available, screening may focus on the detection of early symptoms and signs caused by allergy.

As an example, in the Netherlands a (well-functioning) system has been set up within the bakery sector, since the (raw) materials that are handled (flour etc.) can contain amongst others allergens (such as alpha-amylase). This triage system (starting with a questionnaire, possibly followed by workplace research and / or a medical examination) works well, but there can be a big difference in how one deals with the outcomes:
› In industrial bakeries, people can be placed in another department with less or no exposure, or the sensitized people even leave the sector;
› In traditional bakeries (often family businesses), people often continue to work despite possible health complaints because there is no other alternative.

2.2 Specific information on reported health effects in relation to insects (including crickets)

In the report of the Dutch Health Council (2009), crickets are not specifically mentioned as an known (occupational) allergen. However, in a list of known allergens as provided by NKAL (Nederlands Kenniscentrum Arbeid en Longaandoeningen) [1], Achetea domestica (house cricket) it mentioned as one of the insect allergens, based on the study of Bagenstose III et al. (1980).

Several studies reported health effects for workers working with insects. Laboratory work with insects (i.e. fruit flies, insect larvae, locusts) and insect-breeding (i.e. grasshoppers, tubifex, locust) are associated with occupational asthma (Fishwick, 2012; Cartier, 2015; Raulf et al., 2011; Quirce & Bernstein, 2011), allergic rhinoconjunctivitis, bronchial hyperreactivity (Jensen-Jarolim et al., 2015) and/or anaphylaxis (Moscato et al., 2014).

In a review of risks to entomologists, Stanhope et al. (2015) reported that allergic reactions were associated with exposure to Coleoptera (beetles), Lepidoptera (including butterflies and moths), Araneae (spiders), Blattodea (including cockroaches and termites), Orthoptera (including grasshoppers, locusts and crickets), Diptera (flies), Hymenoptera (a large order of insects, comprising the sawflies, wasps, bees and ants), Ixodidae (hard or scale ticks), Trombidiformes (an order of mites), Hemiptera (true bugs, including cicadas, aphids, planthoppers, leafhoppers and shield bugs), Isoptera (termites), Neuroptera (net-winged insects), Sarcoptiformes (an order of mites and ticks) and Mesostigmata (an order of mites). Entomologists were reportedly working from a few weeks to 28 years prior to experiencing their symptoms associated with contact and/or inhalation and in many instances symptoms became more severe over time. In some cases entomologists were also allergic to the arthropod feed in addition to the arthropods they were working with.

Harris-Roberts et al. (2011) compared the prevalence of respiratory symptoms experienced by entomologists (n=23, prevalence 30%) working with locusts and

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[1] https://www.nkal.nl/content/leidraad-allergenen.asp

Tenebrio molitor, with office workers in the same facility (n=9, prevalence 44%), finding no significant differences in the symptom prevalence. Sensitization, as judged by specific IgE to insects, was only found in those workers currently exposed in the main breeding and dispatch areas, although symptoms without evidence of sensitization were identified in the lesser exposed office areas. A 41-year-old male cricket breeder also underwent a more detailed clinical assessment. This person is highly likely to have had occupational asthma. Serum analysis detected specific IgE to atopy, bran, locust and cricket. He was subsequently moved to the dispatch area of the facility, with no direct exposure to insects, after which his health improved following the reduced exposures.

In contrast, Burge et al. (1980) compared the prevalence of asthma, urticaria, and rhinitis experienced by insect handlers and laboratory personnel working with locusts (25-36% prevalence), field workers with intermittent locust exposure (0-6%), laboratory scientists not working with insects (7-13% prevalence), and administrators (0-7% prevalence), finding that symptoms were clearly most severe for the insect handlers. In addition, atopic workers handling the locusts developed occupational asthma more often and more quickly than similarly exposed non-atopic workers. IgG and IgE antibodies to the locust antigens were found to correlate significantly with both the degree of exposure and the presence of disease.

Bartra et al. (2008) presented a case study of a male assistant in a reptile shop (where he fed reptiles with live crickets, which themselves were fed with cornmeal) with occupational asthma and rhinoconjunctivitis caused by inhaling cricket (Acheta campestris) particles and contact urticaria after handling of crickets. He developed the symptoms after a latent period of 3 years. The patient reported improvement of the respiratory symptoms and disappearance of cutaneous symptoms at the weekend and during holidays. This is the first reported case of unequivocal occupational asthma and rhinoconjunctivitis with contact urticaria in a patient mono-sensitized to cricket.

Linares et al. (2008) presented a case study of a female worker in a cricket farm, who developed rhinitis and bronchial asthma related to her job in a farm where she was exposed to 3 types pf crickets: Gryllus campestris, Gryllus bimaculatus, and Acheta domestica. They stated that crickets are responsible for occupational rhinitis and asthma by an IgE mechanism, and found cross-reactivity among the crickets tested.

In a review Pener (2016) states that cricket allergy is less severe and less common than allergy to locusts and grasshoppers. A partial cross-reactivity exists between cricket and grasshopper allergens. Cricket allergens are proteinaceous compounds, but their nature is insufficiently known; arginine kinase and hexamerin 1B may play a role. Occupational allergy, i.e. allergy of personnel working with rearing and breeding of cricket colonies, is the subject of the majority of reports on cricket allergy. Frequent handling of crickets (for example as fish baits) may inflict allergy which may be considered as a kind of occupational allergy.

A Dutch study focusing on food allergy showed that shrimp-allergic patients, apart from being sensitized for Tenebrio molitor (mealworm), appeared for the most part to be sensitized to Acheta domesticus (house cricket), Zophobas morio (morio or super worm), Alphitobius diaperinus (buffalo or lesser mealworm), Locusta migratoria (African grasshopper locust)), Galleria mellonella (large wax moth) and Hermetia illucens (black soldier fly). These results indicate that there is a risk that these insects also present allergenic risks to shrimp and probably all shellfish allergic patients. The people with a primary mealworm allergy showed varying patterns of sensitization to the various other insects. This indicates that the risk of insect allergy in these individuals is different from that of shrimp or shellfish allergy sufferers. Allergens other than tropomyosin and arginine kinase seem to be involved (Broekman et al., 2017). Although this study focusses on food allergens instead of occupational allergens, this mechanism may also be considered relevant in an occupational context, as workers may be exposed to allergens from several insects.

In an EFSA report presenting a risk profile related to production and consumption of insects as food and feed cross-reactivity of allergens from a specific cricket with allergens from the crustacean is mentioned (EFSA, 2015). The allergens identified were arginine kinase, in addition to glyceraldehyde 3-phosphate dehydrogenase, hence the risk of consumption of these crickets may be comparable to the risk of consumption of crustaceans. An insect component that has been suspected of causing allergic reactions is chitin. Chitin is a naturally occurring polysaccharide of glucosamine, which can be found in the cell walls of amongst others insects (exoskeleton). Chitin and its derivative chitosan are not allergenic themselves, but have immune modulatory properties, depending on the administration route and the size of the chitin particles. Such immunomodulatory properties may have consequences for the expression of allergic reactions to other allergens. EFSA also mentions that there is a there is lack of pre-marketing human results and reports of workers' sensitizations.

2.3 Source(s) of exposure

Although in the articles that described health effects in relation to working with crickets the type of exposure (e.g. specific components of the crickets, specific substances that originate from crickets, specific moments in the life cycle, etc.) are not directly mentioned, it is assumed that the most important source of exposure is the dirt that the crickets produce (combination of cricket poo, parts of cricket exoskeletons and possibly dead crickets, substrate and cricket feed, which in turn can be a breeding ground of all kinds of microorganisms). This dirt can be seen as 'organic dust', that can contain various types of particles. However, also the substrate or the cricket feed themselves may be a source of exposure, to which workers could be exposed as these materials are handled.

Organic dust is dust of biological origin, which consists of several biological agents, for instance proteins (or allergens) from the material itself and (micro)organisms growing in those materials. Biological agents are microorganisms and other carriers of plant or animal origin that can cause adverse health effects in workers after exposure. In addition to living (micro)organisms (e.g. bacteria, viruses, fungi, yeasts and prions), substances or structures that originate from living or dead organisms (e.g. exotoxins, endotoxins, glucans, mycotoxins and allergens) are included.

Workers are most likely to be exposed during either harvesting the crickets or cleaning the crates, when the workers come in direct contact with the dirt. Due to the handling of the dirt, the smaller particles become airborne (forming dust), and can be inhaled by the worker, possibly resulting in adverse health effects. Although during blanching and drying and/or (directly) freezing of the crickets little exposure is expected (as during the blanching the organic dust will be removed, and for freezing the crickets are assumed to be packed), during further processing (grinding) of the crickets exposure to cricket flour (dust-like, that also may contain allergens) can occur. During transportation of the small crickets to the next crate little exposure to organic dust is expected, as the crickets that have just hatched do not produce a lot of poo and also have not yet shed for the first time. During feeding of the crickets also a little exposure is expected, as there is relatively little contact with the crickets and little movement of the air, although it is possible that some organic dust particles become airborne and leave the crate via the opening.

Although exposure is likely to be highest during specific activities related to cricket breeding, it is also expected that there will be a fairly high continuous background concentration of organic dust in the rooms where the crates with crickets are stacked. As the crickets move around and the crates and rooms the crickets are kept in are not assumed to be clinically clean, due to a more or less continuous "vibration" some dust is assumed to be whirled up continuously.

For medium size breeding it is expected that exposure will most likely occur during harvesting, as in this case the crates are tipped over (probably not very gently). This is done in a separate room without control measures. It is reported to be dusty in this room. But also cleaning activities are expected to lead to some level of exposure, as well as the collection of the dirt from the crates to be used as fertilizer (if this is done). In addition, depending on how the processing of crickets by means by grinding is performed (manual or mechanical, open or closed process), and how the cricket flour is handled after grinding (manual or mechanical packaging, scooping or dumping, etc.) the workers performing these task may be exposed to cricket flour, which could also contain allergenic components. Transportation of the small crickets into larger crates and feeding the crickets is expected to result in the least exposure.
Workers work fulltime in these companies. It is unknown if each worker performs a specific task and is thus always working in (a) specific room(s) performing a specific task all day, or that tasks are rotated during the day and each worker will perform several tasks for some time during the working day.

For small size breeding especially the cleaning activities are expected to lead to some kind of exposure, both the cleaning at the end of a cycle and the cleaning in between the cycle. Also during harvesting some level of exposure may occur, but since this is done rather carefully, the level of dust formation is expected to be more limited. In addition, these activities are normally performed outside (where the dust particles spread in the air, diluting the concentration in the air), and these workers only work with the crickets part of the day. Also harvesting and cleaning the crates after a cycle will probably not be done on a daily basis, although cleaning the crates during the cycle can be done on a daily basis. In addition, in case the crates are kept inside their homes, the assumed relatively high background concentration could be a large part of their total cumulative exposure, depending on the time they spend in their homes.

When dust is emitted to the air, this dust will also settle again on all kinds of surfaces, including the body/clothes of the worker. Some of this dust will probably on the hands of the workers, but also on the clothes/skin. If the worker does not clean him/herself after work, he/she may transfer this dust to other rooms or other parts of the house, where the dust can form a secondary source of exposure to which co-workers or family members can be exposed.

2.4 Information about exposure levels

Unfortunately very limited information about actual exposure levels in relation to cricket / insect breeding, either organic dust or allergen exposure levels, is available. Only one study with inhalable dust and endotoxin levels (commonly measured when looking at organic dust exposure) measured during insect breeding (not crickets) is available. Thus no levels of cricket allergens in the air are known.
However, especially in case of exposure to allergens, the exact level of exposure is not always considered to be the most relevant, as workers that are sensitized can already show symptoms when they are exposed to very low concentrations.

Harris-Roberts et al. (2011) performed 21 personal exposure measurements for inhalable dust at an insect breeding company in the UK. Inhalable dust levels in the insect facility (range 1.2-17.9 mg/m³, mean 4.3 mg/m³, SD 4.4) were significantly higher than those in the office area (range 0.1-0.9 mg/m³, mean 0.5 mg/m³, SD 0.3). In 13 out of these 21 samples also endotoxin levels were measured (only 1 sample from the office area). Only six of these were above the lower limit of detection for the assay (1 EU/m³), with the maximum value being 29.435 EU/m³. Unfortunately no further distinction of the exposure levels was made, which makes it impossible to related these levels to certain parts of the breeding process. However, the large variation in both dust and endotoxin levels does suggest that the exposure levels are higher in some parts of the plant, which could indicate that there is a difference in exposure levels depending on the type of activities that take place.

Although organic dust and constituents in this dust are measured on a regular basis in for instance the agricultural industry, insect / cricket breeding is considered too different to be able to use exposure levels from other industries as a proxi for exposure.

In addition, the type of work performed with crickets is that specific that using existing exposure models like ART or Stoffenmanager to estimate exposure levels for this type of work is not considered to be relevant.

3 Control measures to prevent or reduce exposure

3.1 Seven types of exposure prevention

Exposure prevention is the principal aim of any control strategy, although in some cases exposure minimization may be considered sufficient. A hierarchical approach combining varieties of both engineering and operational/procedural control measures is normally applied. In most cases effective control strategies will utilize combinations of several, if not all of the measures.

It should be taken into account that there are probably large differences in what is possible in term of implementation of control measures in Africa compared to the Netherlands. For instance, where robotization / automatization in large production facilities may be considered ‘normal’ in the Netherlands, in Africa a lot of the work is still performed manually (as labour is cheap), and for workers this work may be very important in terms of employment and income generation and such, for which not always many alternatives are available. Thus, where in the Netherlands a person that is sensitized may be transferred to another area in the company or may quit working in this sector, which is called the ‘healthy worker effect’, in Africa that may not always be an option.

In the table below an hierarchical strategy of control measures, in decreasing order of desirability, is presented.

Control measure	General description	Applicability for cricket breeding
1. Elimination / substitution	The most effective form of prevention control is simply to either eliminate the use of the hazardous agent, or the actual process in which it is used. This is not always possible / practicable	Not considered practicable, amongst others because other types of insects are also (known) to be allergenic and human work is preferred for employment rates, especially for youth and women
2. Isolation	Wherever possible processes or operations, which involve some risk(s) to health, should be completely enclosed, with the operator(s) outside the enclosure.	This may be a possibility for harvesting in medium size breeding, where the tipping of the crates may be done more or less automated in an enclosed system. This may also be a possibility for the processing (especially grinding followed by packaging) of the crickets in medium size breeding. This is not considered applicable for small size breeding (too costly).
3. Segregation	Hazardous processes or operations etc. can be segregated from lower risk ones by placing them, for example, at the far end of a workshop, in a separate room, or in a separate building, thereby minimizing the number of workers at risk.	This is already the case in medium size breeding (performing the different activities in different rooms). However, it could be considered to further segregate the various steps of processing. This may not be always applicable for small size breeding, although it is assumed to be a very effective control measure in combination with some form of (low cost) general ventilation. However, the most risky activities are assumed to be performed outside, which

Control measure	General description	Applicability for cricket breeding
		is preferable to performing these activities inside (also in view of possible contamination of the room and possibly the rest the house).
4. Engineering Controls – Ventilation	Processes during which hazardous substances are emitted are commonly controlled by local exhaust ventilation general/dilution ventilation, or a combination of both.	
- Local Exhaust Ventilation (LEV):	Application of mechanical air handling techniques whereby potential airborne contaminants are captured near to the source of emission, extracted, and discharged to either a safe location or subjected to some form of 'air cleaning' technique (e.g. filtration). It is particularly valuable for situations that involve a point source release of hazardous substances.	This may be an effective way to apply in the 'high risk' activities during which peak exposures may occur (harvesting, cleaning, grinding). However, for LEV to be effective, the configuration (location of the hood, air flow, etc.) should be optimal, and should not have a negative effect on for instance the posture of the worker. In addition, it should not have a negative effect on the work process (e.g. a too high air flow may suck the crickets or the cricket powder into the hood). Also the placement of the exhaust of the system should be taken into account (e.g. not into another room) and possible filtration of the air before exhaust (and handling the dust that captured in this way), should be taken into account. This is not considered applicable for small size breeding (too costly).
- General / Dilution Ventilation	Widely used throughout industry for the ventilation of specific rooms. Normally not suitable for the control of (emission of) dust/hazardous substances, also not suitable in situations where the rate of generation of contamination is non-uniform or high.	Not effective in reducing peak exposures (which is the case here). However, smart, low-cost solutions to improve the (natural) ventilation to get as many air changes as possible without having to apply expensive mechanical ventilation may be a good way to reduce amongst others the background concentrations in rooms where crickets are held, and could for instance be applied in combination with segregation.
5. Administrative controls	Administrative controls relate to how the interaction between personnel and the process/operation are organized. Personal factors are essential parts of all control strategies. - Planning (e.g. cleaning during night shift when less people are around) - Job rotation - Stance, work orientation and/or working upwind of the source of exposure by worker - Good housekeeping (clear labelling, good storage, good work techniques, keeping the workplace tidy) - Maintenance schedules, regular inspection, frequent maintenance, examination and testing of machines and engineering controls	These measures are mainly considered relevant in case of medium size breeding. However, as it is not completely clear what the situation (on average) is in medium size breeding companies, and how the work is organized, it is not possible to further distinguish. Especially cleaning practices (of both the crates and the work area) are considered important. Vacuuming (with special filter) is preferred over using broom and dustpan, use of compressed air should be avoided, and wet cleaning is preferred over dry cleaning (crates are already cleaned with amongst other water). When technical control measures are implemented, regular inspection and maintenance should also be considered.

Control measure	General description	Applicability for cricket breeding
6. Information, instruction and training	Education/training of workers on occurrence of health hazards in the workplace and correctly using all control measures provided, adopting recommended operating procedures, wearing and maintaining personal protection (if required), and applying good hygiene practices.	Good hygiene practices may be considered for both small as medium size breeding, but will not always be practically feasible in small size breeding: - No drinking, eating or smoking in work area → separate break room/area - Washing hands before entering and after leaving the work area - Putting on clean work clothing before every shift and when the clothing gets contaminated during work - Washing hands before entering the break room - Taking off work clothing before entering the break room - Washing the work clothing at work / by the company (not taking it home) When technical control measures are implemented, the workers should be trained in how to work with these (new) systems. By means of education / training much can be achieved with relatively little effort. This could include “factsheets” or other forms of simple pictograms to inform people about control measures to be applied and to warn them about the most important health risks. By distributing these or hanging them in the workspace, more companies can possibly be reached then when on each company a ‘live’ training is given.
7. Personal Protective Equipment (PPE)	Because it is better to prevent exposure PPE is normally considered to be the last resort to limit exposure, and only applicable when the preceding measures are insufficient or not reasonably practicable in achieving a satisfactory work situation. Careful consideration must be given to the choice of the PPE device. It is important that the protection is effective and comfortable, especially in case of extended use. Regular maintenance is vital for many types of PPE if effective protection is be obtained. 	Different PPE types could be considered: - Respirators / masks - Protective clothing / coveralls - Gloves / barrier creams - Head nets As inhalation is the assumed to be the primary route of exposure (although exposure via the skin may also be relevant), use of respiratory protective equipment (RPE) could be an effective way to reduce exposure of workers. If used properly, RPE can be a solution in specific actions with a high expected exposure to 1) reduce the peaks of exposure and 2) raise awareness in people that they perform specific actions during which they should be careful. When using RPE it is very important that the right type of RPE is chosen (for particles), that the RPE is worn the right way (e.g. face fit testing), and that the RPE is maintained the right way (e.g. reuse, cleaning, storage). In addition, it is advised to only wear RPE when peak exposures are expected that cannot otherwise be avoided. Wearing RPE during a whole working day is not recommended, partly because it is not pleasant for the worker.

3.2 Main control measures for small scale cricket breeding

Based on the above mentioned findings we recommend the following measures in the small scale crickets farms of Flying Food in order to reduce the exposure to organic dust of workers (production with 20-30 crates):

› Position the crates in a separate farm/ rearing space and not in your home. Based on our earlier experiences in Kenya and Uganda, some small scale farmers positioned the crates for cricket production in their house (around 2% of the farmers), despite our guideline to position them in a separate building. Being day and night nearby the dust around the crates can form a potential health risk for you and the rest of the family;
› Harvesting of crickets has to be done outside, as outside the natural ventilation is better, which reduces the exposure to dust. People work only 1-2 hours a day in their cricket farm and are assumed to be less exposed compared to full time workers. But still workers can get sensitized and for instance develop an allergy;
› Cleaning of crates is recommended to be performed outside, because here the natural ventilation is better;
› Wet cleaning is preferred over dry cleaning;
› Vacuuming cleaning of the farm is preferred over using broom and dustpan;
› The following good hygiene practices are emphasised again:
› Washing hands before entering and after leaving the work area;
› No drinking, eating or smoking in the work area;
› Workers who display symptoms that indicate sensitisation are recommended to use respiratory protective equipment (nose and mouth masks) during harvesting the crickets and cleaning of crates.

3.3 Main control measures for medium scale cricket breeding

Based on the above mentioned findings we recommend the following measures in the medium scale crickets farms of Flying Food in order to reduce the exposure to organic dust of workers (production with more than 500 crates):

› Harvesting of crickets has to be done in a separate ventilated room or outside, because better (natural) ventilation reduces the exposure to dust;
› Cleaning of crates is recommended to be done outside or in a separate ventilated room, to ensure better ventilation;
› Wet cleaning is preferred over dry cleaning;
› Vacuuming cleaning of the farm is preferred over using broom and dustpan;
› Rotate people between harvesting and cleaning crates and other work activities. These activities are expected to lead to the highest exposure levels, and rotation of work activities will make sure that workers are not continually exposed;
› Inform workers about control measures to be applied and warn them about the most important health risks, for instance by hanging “factsheets” or other forms of simple pictograms in the workspace;
› The following good hygiene practices will be taken into account:
  - Washing hands before entering and after leaving the work area;
  - No drinking, eating or smoking in work area;
  - Putting on clean work clothing before every shift, and not wear work clothing when entering the break area;
  - Washing the work clothing at work / by the company (not taking it home).

› Part time and fulltime workers are recommended to use respiratory protective equipment (nose and mouth mask) during harvesting and cleaning of crates.

4 Conclusions

This study focussing on potential health risks of workers in insect breeding and potential preventive measures, gives us the following insights:

1. Looking at the working conditions it is assumed that workers in insect/cricket farms are exposed to organic dust (poo, parts of cricket exoskeletons, possibly dead crickets, egg substrate, cricket feed), which in turn can increase the occurrence of microorganism;
2. Workers are most likely to be exposed during either harvesting the insects/ crickets or cleaning the crates, when the workers come in direct contact with the dirt. Full time workers are more exposed compared to part time workers;
3. Actual exposure levels, either for organic dust or allergens, are unknown. However, especially in case of exposure to allergens, the exact level of exposure is not always considered to be most relevant, as workers that are sensitized can already show symptoms when they are exposed to very low concentrations. Therefore it is important to prevent or at least limit the exposure of workers to organic dust during cricket breeding as much as possible, and apply effective exposure control measures;
4. To get insight in sensitization levels in small and medium cricket farms in Africa, measurement have to be conducted;
5. In order to reduce the risk of allergic reactions at workers working at small scale crickets farms (20-30 crates with in total 50,000-75,000 crickets) we recommend to take the following protective measures:
   a. Position the crates in a separate farm and not in your home;
   b. Harvesting of crickets has to be done outside the farm. Better ventilation lowers the exposure to dust;
   c. Cleaning of crates is recommended to do outside the farm, because of better ventilation. Wet cleaning is preferred over dry cleaning;
   d. Vacuuming cleaning of the farm is preferred over using broom and dustpan;
   e. The following good hygiene practices will be emphasised on again:
      - Washing hands before entering and after leaving the work area
      - No drinking, eating or smoking in work area
   f. Workers who display symptoms that indicate sensitisation are recommended to use respiratory protective equipment (nose and mouth masks) during harvesting the crickets and cleaning of crates.
6. We recommend medium scale cricket farms (rearing with 500 crates with in total 1,2 million crickets) to handle the following protective measures in order to reduce the exposure levels of organic dust to workers:
   a. Harvesting of crickets has to be done in a ventilated, separate room or outside the farm, because better ventilation lowers the exposure to dust;
   b. Cleaning of crates is recommended to do outside the farm, because of better ventilation. And wet cleaning is preferred over dry cleaning;
   c. Rotate people on harvesting and cleaning crates, because these activities has highest exposure levels to dust;
   d. Vacuuming cleaning of the farm is preferred over using broom and dustpan;
   e. The following good hygiene practices will be taken into account:
      - Washing hands before entering and after leaving the work area
      - No drinking, eating or smoking in work area

- Putting on clean work clothing before every shift and when the clothing gets contaminated during work
- Washing the work clothing at work /by the company (not taking it home)

f. Part time and fulltime workers are recommended to use respiratory protective equipment (nose and mouth mask) during harvesting and cleaning of crates.

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