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CLEAN AND EASY CRICKET REARING
– A GUIDE ON HYGIENIC BUILDING DESIGN IN REARING FACILITIES

SANDRA MELLBERG AND GUN WIRTANEN

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ABSTRACT

This report provides guidelines for farmers interested in building up a hygienic cricket farm. The report is a part of ENTOLAB - *Hyönteiskasvatuksen edistäminen Etelä-Pohjanmaalla (Insect Rearing in Southern Ostrobotnia)*, a project that started in 2016, with the intention of exploring the potential of insects as nutrition for both humans and animals. This report is based on the European Hygienic Engineering & Design Group (EHEDG) document 44 on Hygienic Design Principles for Food Factories, which provides general instructions for food establishments. Consequently, this report is a basic guide with the aim to implement existing primary production guidelines to the novel production of crickets as food and feed.

The popularity of rearing crickets for food and feed has increased in Finland. In September 2017, the Finnish Ministry of Agriculture and Forestry made a reinterpretation of the EU Novel Food Regulation regarding products containing whole insects. This enabled selling insects as food to consumers. Several guides concerning insect rearing have been published lately; however, information about the hygienic aspects of insect rearing is limited and there is still no standard processing procedure in place for cricket farmers.

The recommendations given in this report are mainly hygienic aspects such as, control of farm surroundings, materials used inside the farm and their cleanability, air flows, personnel and material flows, temperature, humidity etc. An obstacle that some cricket farmers are dealing with is how to keep the rearing as hygienic as possible while keeping a high humidity and fairly high temperature in the rearing room. A hygienic cricket farm is achieved by considering cricket rearing the same way as traditional primary production and ensuring that the following basic hygiene criteria is met.

TIIVISTELMÄ

PUHDAS JA HELPPOHOITOINEN SIRKKAKASVATUS – OPAS KASVATUSTILAN HYGIEENISEEN SUUNNITTELUUN

Tästä raportista löytyy kiinnostuneille kasvattajille ohjeita, kuinka luoda hygieeniset sirkkakasvatustilat. Raportti on osa lokakuussa 2016 alkanutta *ENTOLAB - Hyönteiskasvatuksen edistäminen Etelä-Pohjanmaalla* -hankketta, jonka tavoitteina on edistää sekä hyönteiskasvatuksen kehittymistä että tuotantoa ruoaksi ja rehuksi. Ohjeistus tässä raportissa pohjautuu *European Hygienic Engineering & Design Groupin* (EHEDG) ohjeeseen 44 *Hygienic Design Principles for Food Factories* (*Hygieenisen suunnittelun periaatteet elintarvikealalle)*, joka sisältää yleisiä suunnitteluohjeita tuotantotiloissa. Raportista löytyy informaatiota, miten voidaan rakentaa helposti puhdistettavia tiloja huomioiden nykyiset alkutuotannon suuntaviivat sirkkojen tuotannossa ja tilojen hygieniavaatimukset elintarvike- ja rehutuotannossa.

Sirkkakasvatuksen suosio ruoaksi ja rehuksi on kasvanut Suomessa. Syyskuussa 2017, Maa- ja metsätalousministeriön edustajat tulkitsivat EY:n asetuksen uuselintarvikkeista ja elintarvikkeiden uusista ainesosista siten, että tuotteita kokonaisista hyönteisistä saa olla kaupan 2018 loppuun saakka. Tämä sallii hyönteistuotteiden myynnin ruokana kuluttajille. Viime aikoina on julkaistu useita oppaita hyönteiskasvatuksesta. Tietoa hyönteisten kasvatuksen hygieniaan liittyvistä näkökohdista on vähäistä eikä sirkkakasvattajilla ole olemassa vakiintunutta käytäntöä tilojen rakentamiseen.

Tämän oppaan suositukset liittyvät sirkkatilojen rakentamiseen ja erityisesti hygieniaan liittyviin olosuhteisiin, kuten kasvatustilan ympäristö, kasvatustilassa käytettyjen materiaalit ja niiden puhdistettavuus, ilma-, henkilöstö- ja materiaalivirrat, lämpötila, kosteus jne. Joidenkin sirkkakasvattajien ongelmana on ollut kasvatustilan pitäminen mahdollisimman hygieenisenä, sillä kasvatustilassa on korkea ilmankosteus ja korkeahko lämpötila. Hygieeninen sirkkakasvatustila saavutetaan kasvattamalla sirkkoja alkutuotantotiloissa varmistaen, että perushygieniaa koskevat vaatimukset täyttyvät.

SAMMANFATTNING

REN OCH ENKEL SYRSUPPFÖDNING – EN GUIDE FÖR HYGIENISK DESIGN AV ODLINGSUTRYMMEN

Denna rapport ger riktlinjer till uppfödare som är intresserade av att bygga upp en hygienisk syrsodling. Rapporten är en del av ENTOLAB - *Hyönteiskasvatuksen edistäminen Etelä-Pohjanmaalla (Insektsuppfödning i Södra Österbotten)*, ett projekt som startade år 2016 med syftet att utforska insekternas potential som näring till människor och djur. Rapporten är baserad på *European Hygienic Engineering & Design Group (EHEDG)* dokument 44, *Hygienic Design Principles for Food Factories*, som består av generella instruktioner för företag inom livsmedelsbranschen. Således är denna rapport en grundläggande guide med målet att tillämpa existerande produktionsriktlinjer till den nya produktionen av syrsor som livsmedel och foder.

Populariteten av att föda upp syrsor har ökat i Finland de senaste åren. I september 2017 gjorde det finska jord- och skogsbruksministeriet en nytolkning av EU:s förordning om nya livsmedel, gällande produkter innehållande hela insekter. Denna tolkning möjliggjorde försäljning av insekter som mat till konsumenter. Ett flertal guider gällande uppfödande av insekter har publicerats under de senaste åren, men det finns sparsamt med information om de hygieniska aspekterna inom insektsuppfödning. Det finns inte heller någon standard procedur för syrsuppfödning.

De rekommendationer som rapporten ger angående syrsuppfödning är främst hygieniska aspekter, såsom kontroll över odlingens omgivning, vilka material som skall användas samt deras rengörbarhet, personal- och materialflöde, temperatur, fuktighet etc. Ett hinder som vissa uppfödare har varit tvungna att lösa är hur man ska gå tillväga för att hålla uppfödningsutrymmet hygieniskt, då luftfuktigheten är hög och temperaturen förhöjd. För att åstadkomma en hygienisk syrsodling ska grundprinciperna för traditionell primärproduktion och grundläggande hygieniska krav inom livsmedelsproduktionen betraktas.

1. INTRODUCTION

The popularity of rearing insects for food and feed has increased due to Finland making a reinterpretation of the EU Novel Food Regulation regarding whole insects, which enabled selling insects as food to consumers (Evira, 2018b; Finnish Ministry of Agriculture and Forestry, 2018; Tuohinen, 2017). Several guides concerning insect eating and farming have been published lately; however, information about the hygienic aspects of insect rearing is limited and there is still no standard processing procedure in place for insect farmers (Dobermann, Swift & Field, 2017).

This practical guide to cricket rearing focuses on hygienic cricket rearing. Furthermore, it provides guidelines for farmers who would like to build up a small-scale cricket farm taking the hygienic building design into account. This topic is covered extensively in the European Hygienic Engineering & Design Group (EHEDG) document 44 on Hygienic Design Principles for Food Factories (EHEDG, 2014), which is mainly aimed for large scale production. Insects as a new food group also poses challenges as research in this product group is limited and all risks are still not known. As insect rearing categorizes as primary production, this guide is based on general instructions for food establishments in primary production. Consequently, this guide tries to implement existing primary production guidelines to the novel production of insects as food and feed.

In accordance with Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety, primary production in the food industry is defined as production, breeding or farming, including harvesting, milking, slaughter, egg production and insect rearing. Also hunting and fishing wild animals is primary production. Transport, handling and storage of these products are all considered as a part of primary production, as long as the nature of the product does not change. As soon as the nature of the product is changed, e.g. by roasting, peeling or frying, the production is defined as food processing (Figure 1). Producers already engaged in other primary production, i.e. pig or dairy farm-

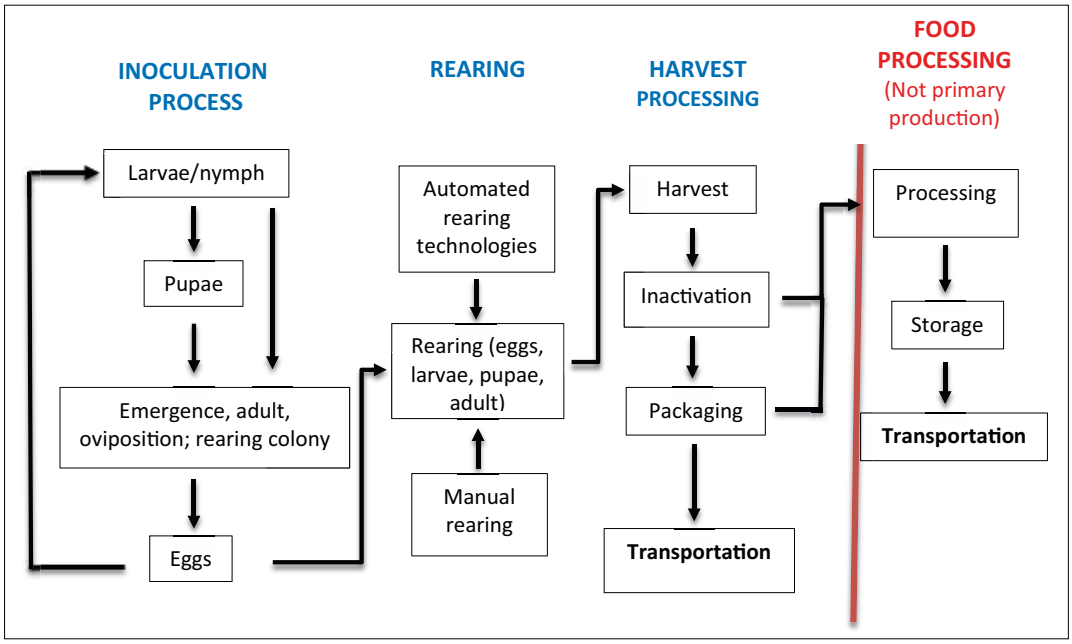

Figure 1. Primary production phases in insect rearing are shown in blue and food processing in red (based on Dobermann, et al., 2017)

ing, may report that their primary production also covers insect rearing for use as food (Evira, 2018a).

It is the operator's responsibility to maintain the hygiene in the insect food production (Evira, 2018b). The production of insects as food is under the same law as any other food production and regulated by the European Union through national laws. Food and Agriculture Organization (FAO 2011) also states that everyone, including farmers of both animals and crops, manufacturers and processors, food handlers and consumers, has a responsibility to assure that food is safe and suitable for consumption. The rationale that FAO has formed for primary production is: "To reduce the likelihood of introducing a hazard which may adversely affect the safety of food, or its suitability for consumption, at later stages of the food chain."

To achieve this, the establishment, including all food premises, facilities and equipment should be located, designed and constructed to ensure that:

- contamination is minimized,
- design and layout permit appropriate maintenance, cleaning and disinfections and minimize air-borne contamination,
- surfaces and materials, in particular those in food contact, are non-toxic in intended use and, where necessary, suitably durable, and easy to maintain and clean,
- temperature, humidity etc. are appropriate and controlled, as well as
- effective protection against pest access and harbourage are available in the facilities

In other words, attention to good hygienic design and construction, appropriate location, and the provision of adequate facilities, is necessary to enable effective control of hazards.

2. SITE REQUIREMENTS

When constructing facilities for a cricket farm it is important to consider the surroundings that could affect the rearing (EHEDG, 2014). Cricket farms should be sited with due regard to the provision of services needed and to avoid contamination from neighbouring activities. The site should be designed, constructed and maintained in a manner to prevent conditions that contaminate food or disturb the cricket rearing.

2.1. SITE SURROUNDING

There are multiple environmental aspects that should be considered, when choosing the rearing site. The site should be free of contaminating industrial activities and open water sources, which could attract birds, insects and rodents that all harm the cricket rearing (EHEDG, 2014). Waste areas and pests should also be avoided. It is important not to mix the reared insects with the wild insects, thus structures and vegetation that could harbour wild insects should be avoided. Mixing wild and reared insects could lead to pathogenic contamination or destruction of the ecosystem, either in or outside the farm. Wild insects are as unwelcome in the insect rearing industry as in the food industry. Insects are defined as pest, along with other vermin e.g. rodents.

To protect the site from pests, the farm should be placed with enough space from meadows and forests (Figure 2). EHEDG (2014) recommends that shrubs and plants should be located at least 3 m from buildings while trees should be 9 m away from the building. To minimize insects drawing to lamps, all entrances and walkways should be appropriately lit. External lightning that illuminates the farm/factory should be placed in locations away from the entrance(s) of the building to avoid attraction of outside insects close to the entrance. On the outside, parking lights and building lights should be angled downwards, or towards the building. Never out and away from the building, since lights showing outwards will attract insects to the building when it is dark outside.

The site should be protected against (EHEDG, 2014):

- neighbouring facilities and activities creating possible contamination sources, e.g. farms, heavy chemical industries etc.,
- areas where waste cannot be removed effectively,
- rivers, canals, ponds, marshes and other waterways,

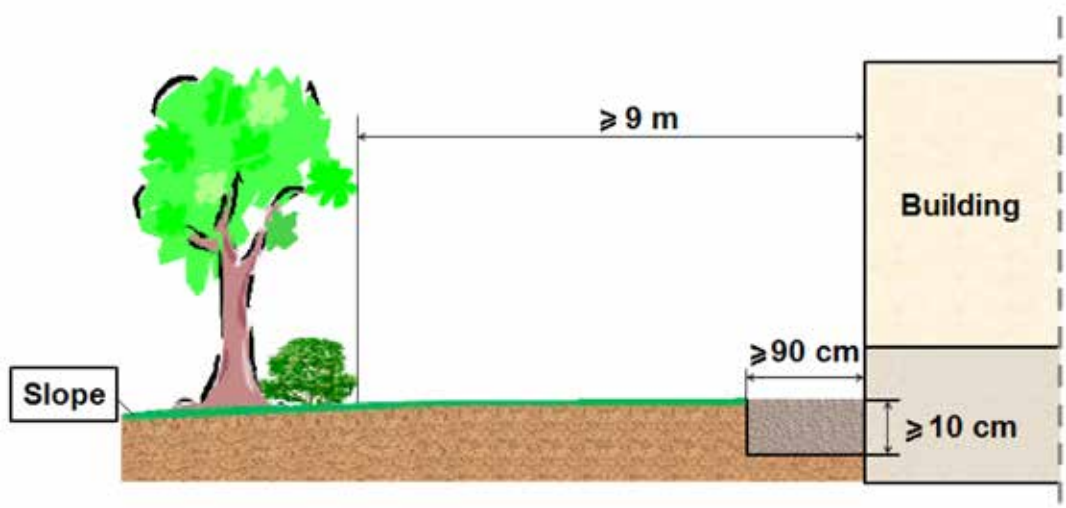

Figure 2. The farm should be constructed with adequate space from vegetation, e.g. by using a gravel walk with no vegetation and sparse vegetation on the lawn (EHEDG, 2014)

- areas subject to flooding,
- areas prone to infestations of pests,
- areas prone to excessive levels of airborne bacteria, yeasts and moulds as well as
- loud external noise that could disturb the rearing of the crickets.

Furthermore, the site should be locked to prevent outsiders from getting into the building e.g. persons carrying out petty crimes, fraud and bioterrorism (EHEDG, 2014).

The site should have (EHEDG, 2014):

- clearly defined boundaries to keep out animals, pests or unauthorised persons,
- no open water ways that attract birds, insects, rodents etc.,
- minimal vegetation and foliage. When present, shrubs and plants should be located at least 3 m and trees at least 9 m from the buildings,
- an area of minimum 60 cm to 90 cm around the building, i.e. a gravel walk, which is free of grass, weed, flowers, plants, and other vegetation
- weed control to reduce harbourage for insects and rodents but also to prevent air-borne seeds getting into the factory, and
- general facilities designed to meet security and pest control strategies and if needed separate utility buildings, trailers, garages, waste water treatment facilities, storage sheds, and guard shacks.

A site plan is a useful tool for a new plant design. The plan should consider the management of hazards as a part in the Hazard Analysis and Critical Control Points (HACCP) procedure (EC 178/2002; Evira, 2017).

2.2. BOUNDARY FENCES AND WALLS

The main role of fences and walls is to keep the site secure from unwanted pest and human activities (EHEDG, 2014). The boundary fence and wall could be constructed as a concrete or brick wall base above ground level that should prevent the passage of both rodents and flooding. The fencing must form a barrier to both wild and domestic animals e.g. cats and dogs as well as rodents. On both side of the fence or wall, a minimum area of 50 cm should be clear of trees, bushes, plants, waste and structures. The fencing should be high enough to effectively prevent intrusion. Ideally access should be limited to a single lockable entrance to the farm, to support the farm control.

2.3. BUILDINGS

Cricket rearing is a space-efficient activity and is therefore easy to carry out (van Huis, et al., 2013). Popular ways of initiate a rearing facility is to convert already existing facilities, i.e. old piggeries or unused in-house rooms, into a cricket farm or use intermodal containers as cricket rearing facilities (de Sousa, Warren, & Rekomaa, 2018). In an assessment of a building's appropriateness for cricket rearing, the following aspects should be considered (EHEDG, 2014):

- the level of factory floor should be higher than the surrounding ground to protect it from demolition and contamination,
- there should be adequate space above, below and around equipment and service structure to enable easy cleaning and maintenance,
- Excess entrances and windows should be locked to enhance control and
- the flow of insects, personnel and waste should be designed in order to minimize cross-contamination (Figure 3)

When assessing the building design for good hygienic operations it is important to provide protection against physical, chemical or biological contamination, i.e. wild insects, dust, moisture, smoke, microbes etc. (EHEDG, 2014). This is achieved by considering the following aspects:

- Prevent entry of contaminants from doors, windows etc., by keeping them closed or using insect-proof screens and/or self-closing mechanisms. The air intakes with filter systems should be appropriately located on the roof. The roof, walls and foundations should be maintained to prevent leakage.
- Prevent entry and harbouring of pests, birds and wild insects. Holes, drains and other places likely to be harboured, e.g. places that are not in continuously use, should be sealed.
- No structure or equipment, which could provide places for microbial contamination or harborage for invasion, is allowed.
- Reduce cross-contamination by segregation, which considers the flow of e.g. air, personnel, materials, products and waste.
- Separate storage areas for raw materials, packing materials, chilled or frozen products as well as cleaning tools and agents etc. These areas

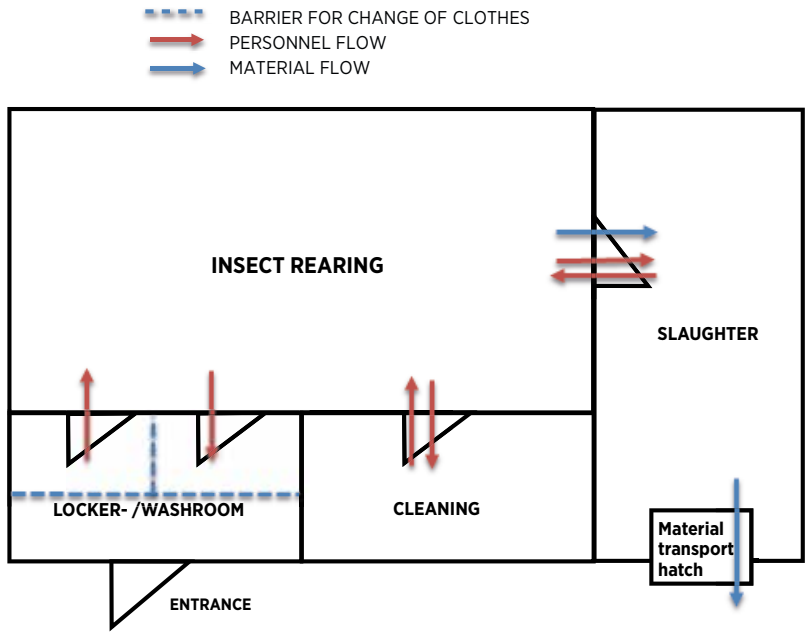

Figure 3. An example of how a cricket farm could look like taking personnel and material flow into account.

must also fulfil other safety laws and directives e.g. that cleaning agents should be kept in locked cupboards.
- Maintain feed at appropriate temperatures and allow monitoring of these temperatures
  - in the room where the crickets are reared and
  - in freezers where the crickets are killed and stored
- Have few personnel entries or openings acknowledging security and fire escape requirements to prevent contamination from people.

It is important that the design and layout is appropriate for the activities in a hygienic room, which should (EC 852/2004; EHEDG, 2014):
- protect against accumulation of dirt and shredding of particles into food,
- protect against contact with toxic materials, dirt, dust, fumes, smoke and other contaminants,
- protect against condensation and undesirable growth of mould, yeast and bacteria (or microbial growth) on surfaces
- permit sufficient cleaning and/or disinfection and maintenance,
- allow immediate drying after cleaning and disinfection and
- provide sufficient lightning and ventilation

The equipment inside the farm must be designed, constructed and installed so that they do not cause food contamination, are easy to clean and do not provide harbourage for pests (EHEDG, 2014). Additionally, it needs to be adequate space between equipment and wall, floor, ceiling or door to prevent the accumulation of dirt and to facilitate cleaning, maintenance and inspection (Figure 4). Furthermore, the equipment shall not be placed directly over floor drains.

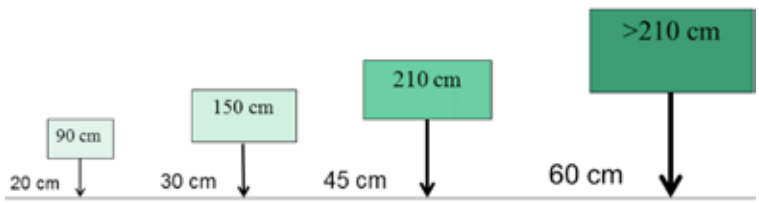

Figure 4. All equipment should be placed with adequate surrounding space (EHEDG, 2014).

3. SEGREGATION

Insect rearing needs to be segregated from other activities. It is not, per se, possible to rear insects in the same greenhouse where plants are growing, because it is difficult to organize the actions in a way that does not imply food safety risks (Evira, 2018b). A possible escape of insects from the rearing boxes to the growing plants could create problems. Furthermore, in the greenhouse, there are probably other insects, which could easily mix with the reared insects and possibly result in e.g. insect diseases. Operators should always be aware of not letting out the reared insects in the nature or other environments, regardless of the surroundings.

3.1. INTERNAL DIVISION AND ZONES

All food processing operations should be carried out in a way that minimise the risk of contamination. The non-food activities outside the cricket farm should be effectively separated from food production, physically with walls, as well as via airflows and trough drainage (EHEDG, 2014).

Hygienic building design is essential, particularly in food production (EHEDG, 2014). The three hygiene levels that needs to be considered in food production are basic, medium and high hygiene areas, which all are formed according to the products preparation stage (Table 1). All areas in the food production that does not handle food in any way are called "non-food production areas" and offices, canteens, locker rooms and toilets are examples of such areas. The rearing area itself needs to be segregated from non-food production areas associated with insect rearing and changing rooms, toilets etc. should therefore be located outside the rearing room. However, there should be hand-washing points both in the rearing and in the processing areas.

Basic hygiene is the first stage zone in a food production facility, where the raw materials enter the preparation phase (EHEDG, 2014). Basic hygiene is the criteria for primary production and therefore, insect farming shall include good product flows, ease of cleaning, personal hygiene and hand washing, ease of maintenance, potable water supply and waste control. Building design in the basic zone may be simple with e.g. smooth concrete floors, exposed steel work and natural, screened ventilation and lightning. Primary production must meet the basic hygiene criteria as well as basic *Good manufacturing practices* (GMP).

After the product have gone through basic hygiene area, such as rearing and killing of insects, it continues to further processing where medium and high hygiene criteria should be applied. This includes the processing of a raw insect into a food product that is yet to be prepared. Most of the food handling activities is performed in this zone, including the first stage of meat and fish, fresh fruit, vegetables products as well as beverages (EHEDG, 2014). The hygienic implications of these areas are as much about the prevention of the hazards spreading to other (cleaner) areas in the factory as to the prevention of contamination to the product from the processing environment.

When the product reaches its final step in the food processing chain, it goes into the high hygiene area, where all treatments after the last heat-treatment and before packaging are undertaken, e.g. slicing, chopping etc. of ready-to-eat (RTE) products (EHEDG, 2014). This is the most critical area, where the final microbial reduction steps are carried out. High hygiene area continues until the product is in its primary packaging, thereafter further activities can be realised in other zones.

To be able to determine how many processing levels or zones are needed, a "Zoning hazard analysis" can be realized (EHEDG, 2014). The analysis could be implemented by examining the hazards present in raw materials or in the processing environment, by knowing how the people, products, waste, water and air flow within the factory as well as knowing the microbial growth of the producing products. However, insect rearing requires only basic hygiene areas and non-food production areas. In case the operator decides to further process the insects, medium and high hygiene zones are also needed.

3.2. STORAGE

Storage areas is essential in all farming systems and as mentioned in the previous section, segregation needs to be considered. The storage areas should be designed to permit adequate maintenance and cleaning, avoid pests and harbourage, protect food from contamination and separate dry areas from wet areas (EHEDG, 2014).

Table 1. Hygiene levels in food production (EHEDG, 2014).

Term	Description
Site barrier	Security fencing, gatehouse
Site	Grounds, driveways, rubbish tips/trash management areas
Building envelope	Foundations, floors, walls, roofs, air filtration
Non-food production area	Areas not associated with rearing or manufacturing processes, e.g. offices, utility rooms, locker rooms, toilets
Rearing area barrier	Physical barrier from the non-production area. Develop concept of "you are now entering a food production area". Protective clothing is to be worn and hand washing to be undertaken.
Basic hygiene areas (basic GMP and GHP apply)	- Primary production or any manufacturing area in which raw materials and/or finished products (within their primary packaging) and packaging/labelling materials are received, sampled or stored prior to despatch. - Areas in which raw agricultural products are sorted and cleaned. - Areas in which insect slaughter or killing is started. - Areas in which waste is handled. - These areas should be designed to minimize spillage and product harbourage and avoid cross contamination.
Medium hygiene barrier	Basic physical segregation by means of walls and doors. Hand washing required upon entry to Medium hygiene area. Requirement for operatives to change footwear or clothing is on hazard analysis basis.
Ingredient preparation area (All GMPs and GHPs apply)	- Area in which legislated food-handling activities is undertaken. - Areas where products are subject to further processing and are known to have the potential to be contaminated. - Food safety risk is low
General food processing area barrier	Physical segregation by means of walls and doors. Hand washing required upon entry to general processing area. Requirement for operative to change footwear or clothing is on hazard analysis basis
General processing area (All GMPs and GHPs apply)	- Area, in which raw materials are received, sorted and sampled. - Area within the plant where products susceptible to contamination and/or microbial growth are treated or handled. - Food Safety risk is Medium
High hygiene barrier	Physical segregation via walls, floors, air curtains or air pressure (3-5 Pa) and drainage. Entrance of products via a decontamination step. Entrance of packaged, decontaminated ingredients via an outer packaging decontamination step. Controlled packaging entry procedures. Entrance of utensils, tools, equipment etc. via a decontamination procedure. Personnel entry via a changing room, sluice etc. where clothing, captive footwear and gloves are changed.
High hygiene area	- Any manufacturing area where microbiologically decontaminated ingredients or formulations are sampled, handled or further processed and where such activities expose the product to microbiological contamination and where such products may allow the survival or growth of spoilage and pathogenic microorganisms and where these food products are intended to be consumed as supplies without a heat cooking step, e.g. ready to eat - Food safety risk is high

GMP - Good Manufacturing Practices. All procedures, processes, practices and activities aimed at ensuring that the suitability and safety objectives are met consistently.
GHP - Good hygiene Practices. Measures applicable throughout the food chain (including primary production through to the final consumer), to achieve the goal of ensuring that food is safe and suitable for human consumption

Freezing is currently the main killing technique for cricket farmers as this is generally considered a natural and humane way of killing the insect (van Huis et al., 2013). Afterwards the crickets are stored in the freezers until they continue to further processing. Therefore it is important to keep them stored at correct temperature and monitor the storage freezers continuously. Since the temperature in the rearing room is usually much higher than normal room temperature, the freezers could be advantageously placed in a different room with a lower temperature to ensure the low storage temperature. If thawing of crickets for further processing occurs at the farm, equipment and rooms must be designed with adequate drainage and environmental moisture control to prevent condensation (EHEDG, 2014).

4. PERSONNEL AREAS

Operatives working in the farm are likely to be wearing contaminated clothes, footwear and hands upon arrival at work (EHEDG, 2014). Therefore all clothes should be changed into work wear in a separated changing facility before entering the rearing room. The changing facilities should be sited to allow personnel direct access to the production and a barrier, e.g. a door, should be placed between the changing room and the rearing area, so that the operator knows where to change clothes (Ruralia institute, 2018). To minimize contamination risks, two doors should be installed in the changing room, one for entrance into the rearing room and one for exit back to the changing room (Figure 2).

When changing into work wear, following step needs to be implemented (EHEDG, 2014):

1. Remove street clothes and footwear and put on hair or beard net, so that all lose hair stay out of the rearing area. Put on factory protective clothing and footwear (wash protective clothing regularly).
2. Wash hands properly
3. Enter the rearing area via a hand disinfection station

4.1. HAND HYGIENE

Hand hygiene is essential in food manufacturing and the provision of hand hygiene facilities is usually a legal requirement (EHEDG, 2014). Proper hand washing protects you and the animals from contagious diseases (Ruralia institute, 2018). Washbasins should be provided with taps for hot and cold water or temperated water, dispensers for hand-wash and hand-rub agents as well as dispensers for disposable paper towels or kitchen paper rolls (Aarnisalo et al., 2006; Wirtanen et al., 2014). Reusable hand towels shall not be used. Facilities for washing equipment, utensils and containers should be separate from hand washing areas (EHEDG, 2014).

4.2. TOILETS

Toilets are placed outside the food production area, in connection to the changing room so that no one will go to the toilets before changing to civilian clothes (EHEDG, 2014). After using the toilet, there should be two hand basins prior to re-entering the production areas: one in the toilet and one at the entrance to the production/rearing area. No toilet facilities shall be located in the high hygiene area.

4.3. CLEANING FACILITIES

Facilities for cleaning, disinfection and storage of working utensils, tools and equipment should be separated from production, food storage and processing and packaging areas to prevent contamination (Aarnisalo et al., 2006; EHEDG, 2014; Wirtanen & Salo, 2014). The cleaning agents stored in a locked cupboard should not be inside the rearing room, because of the risk of chemical contamination of the insects.

5. BUILDING ENVELOPE

5.1. FOUNDATIONS

The foundation is one of the most important element in a building structure (EHEDG, 2014). A well-constructed and reliable building needs a steady foundation appropriate for the soil type and structural loads. This notion is increasingly important in the context of hygiene in food production, as food is sensitive to microbial growth, pests and rodents. If the building tilts, due to e.g. earth or water pressure, the foundation will crack and thus cause hygienic risks and instability. To ensure stability and prevent attacks from burrowing rodents, the foundation should be at least 60 cm below ground and coated e.g. with waterproof asphalt. For additional prevention of pests and rodents entering the building, the foundation should be filled out with concrete, designed like the shape of an L, 610-915 mm below ground level (Figure 5).

5.2. ROOFS

Roofs are a major source of microbial growth and therefore all routes of contamination from the roof into the building should be controlled, via personnel access, air intakes as well as unintended leakage (EHEDG, 2014). The roof should also be sloped at least 1-2% to ensure drainage of dirt and rainwater. For flat roofs, water can be transported into a gravity or vacuum/siphonic system outside the hygienic areas (see pp 47-48 in EHEDG, 2014). However, a flat roof may attract birds due to its horizontal surfaces (although ledges and architectural elements suitable for bird nesting often occur on other type of roofs). Bird spikes can be used to prevent bird nesting.

Roofs should provide a barrier against infiltration, be waterproof and easily cleanable (EHEDG, 2014). Roofs containing stone ballast are not clean-

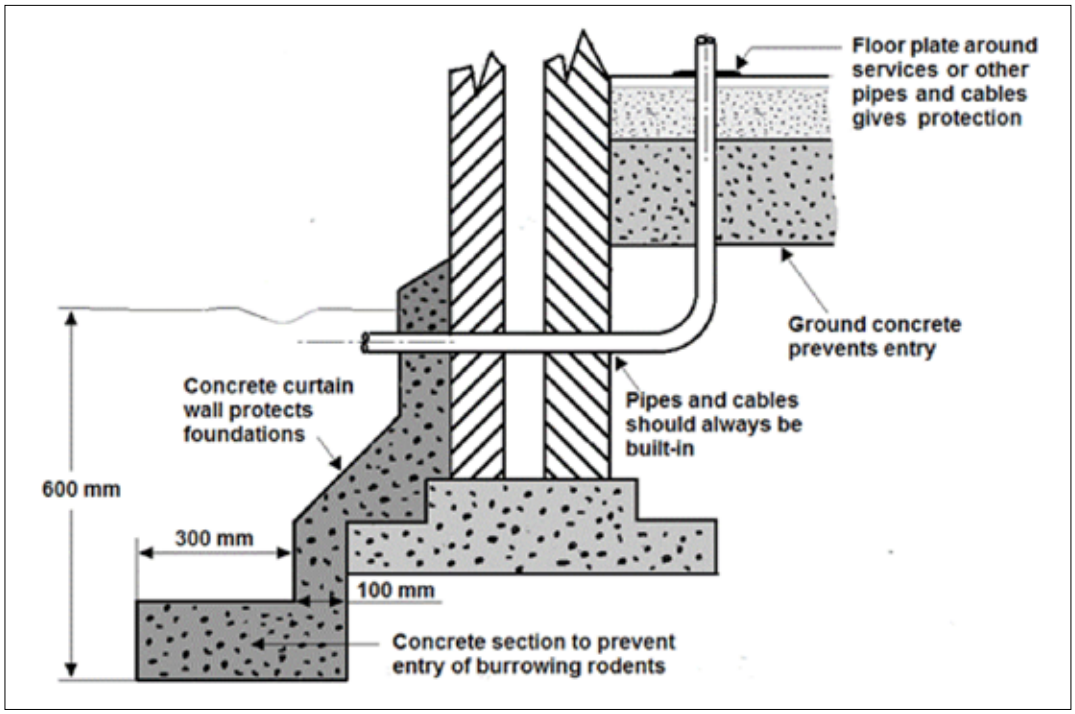

Figure 5. Protecting the building from pests can be done using concrete-filled, L-shaped foundation at least 600 mm below the ground level (EHEDG, 2014).

able and should therefore be avoided. Also "eco-friendly" roofs, which favour the growth of grasses and other plants, are not cleanable and could harbour pests. The roofs must be fully sealed with access only from outside the building. Furthermore, the roof must tolerate exposure to changing weather conditions, increased environmental pollution, structural-physical exposures and mechanical stresses. Protective functions, like roof cladding, may be suitable for roofs that are situated in these environments.

When the outside temperature varies with the different seasons, and drops to low temperatures, an insulation of the roof is to be considered. The installation of an insulated double sheet roof will get almost independent from the weather conditions, which in turn will protect the crickets from intense temperature variations (EHEDG, 2014). An insulated roof also stabilizes condensation inside the farm. Condensation occurs when low temperature air is exposed to material of higher temperature.

5.3. FLOORS

The foundation for a safe, hygienic food production is a floor suitable for its purposes. Floors are critical areas considering microbiological aspects (EHEDG, 2014). For instance *Listeria monocytogenes* are likely to be found on wet floors (in biofilms). Therefore all floors must be easy to clean and, where necessary, to disinfect. There are three levels of poor hygiene regarding floors:

- failure of floor installation, e.g. between the sealant and the tiles,
- failure of floor interfaces, e.g. gaps between floor drains and the floor itself,
- failure of flooring material, i.e. not taking into consideration what kind of floor the actions require

Cleaning in cricket farms is however, different from other primary production since it is important not to allow the insects to escape (Evira, 2018b). Therefore any floor drains must be placed outside of the rearing room, e.g. in changing rooms or storage rooms. If fluids are generated from floor cleaning outside the rearing room, it should be effectively removed using floor drains, which in turn must be connected to a drainage system (EHEDG, 2014).

5.3.1. FLOORING MATERIAL AND STRUCTURE

There are many flooring systems that may be appropriate for small scale operations and the most important aspects to consider when choosing a floor material is that it must endure wear and be non-absorbent (EHEDG, 2014). Cementitious and very lean resin floors are often porous which can be very short lived in service, while tile is a good cleanable choice for insect rearing since tiles perform well in moist areas. Although it is important that the joints are even and properly sealed (Figure 6). The smaller the joints in tile floors are the better these tiles perform in wet or moist areas.

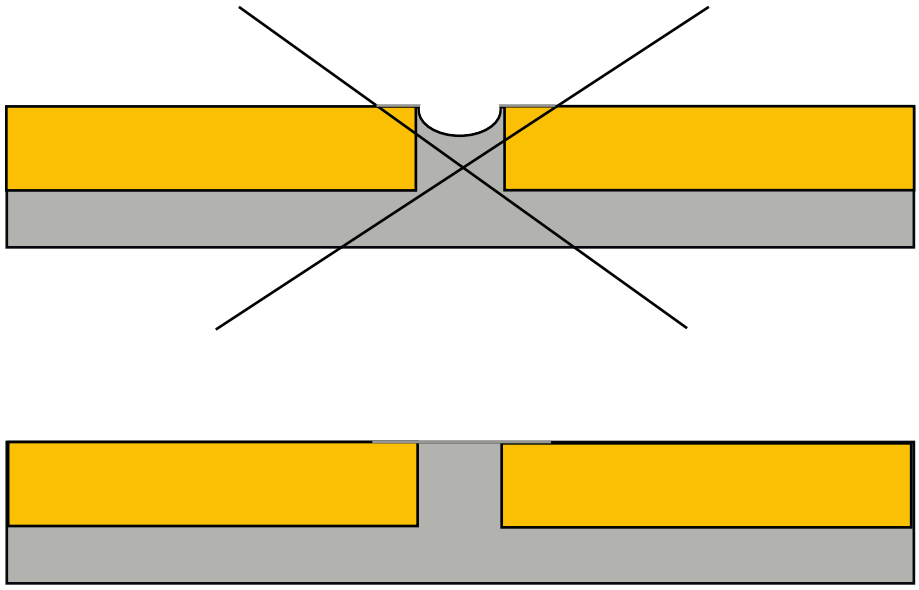

Figure 6. Proper jointing of tiles. Incorrect (top) jointing and correct (bottom) (EHEDG, 2014).

Concrete floors are suitable in basic hygiene areas and acceptable for insect rearing, but because of its porous character it is not suitable for food and beverage processing, nor is it cleanable. Cement grouts is also suitable for primary production but not food processing, as resin grouts is the essential hygienic option for food processing areas. Sheet flooring systems (vinyl, linoleum, rubber) may also be appropriate to small scale operations, but the effective sealing of joints are critical to these materials as they are easily cracked after the fall of a sharp object. Surface defects have negative impact on floor hygiene. A failing floor is neither hygienic, safe nor attractive and could lead to food contamination and accidents.

5.3.2. FLOOR CLEANING AGENTS

Watch out for strong chemicals used in cleaning and disinfection. They can be too strong and not suitable for the flooring material (EHEDG, 2014). Alcohol-based can be used in surface disinfection, but some solvents and essences e.g. peppermint oil can be aggressive. Other aggressive disinfectants are sodium hypochlorite, peracetic acid and hydrogen peroxide.

5.3.3. COVINGS AND KERBS

The junction between the wall and the floor is a critical zone from a hygiene perspective and has to prevent the accumulation of soils and promote the ease of cleaning and prevent water from penetrating the wall (EHEDG, 2014). To minimize these risks, the floor can be coved at junctions (Figure 7). In addition, all joints and edges must be sealed. Since this is a way to reduce any potential openings, the risk of crickets escaping also reduces. A kerb, which is a thick skirting placed in the junction between the walls and the floor, can be used to protect the wall from damage and keep them in a hygienic condition. If doors or walls become damaged, pests and microorganisms may be harboured or crickets might escape into the nature. However, it is important not to install any kerbs with horizontal surfaces but instead use kerbs formed with a bevelled top edge (to prevent dirt accumulation and allow any liquids to run off) and to keep the coving between floor and kerb (Figure 8). Coved skirting improve cleanability and hygiene and to prevent the water from running into the floor-to-wall junction. The kerb should be of non-porous material and easy to clean.

If equipment is to be installed in the floor, all joints and edges must be sealed to prevent dirt accumulation and facilitate cleaning. That is, joints are weak points and will become maintenance items. Therefore they should be placed away from areas where liquids usually gathers, e.g. vessels

Figure 7. A coved sheet flooring system (EHEDG, 2014).

Figure 8. Kerbs with a bevelled top edge and coved at wall-floor junction (EHEDG, 2014).

5.4. WALLS

5.4.1. EXTERNAL WALLS

All external walls should be weather, water, insect and rodent proof. Rats fit through 12.7 mm holes and mice through holes as small as 6.4 mm. Walls need to be well isolated, easy to clean and contain no cold bridges. Horizontal surfaces that might give harbourage for birds, insects or rodents needs to be reduced, both on top of and under protruding edges.

5.4.2. INTERNAL WALLS

EU regulation 852/2004 states that "wall surfaces are to be maintained in a sound condition and be easy to clean and, where necessary, to disinfect." To achieve this, the inside walls need to be durable, which means that they must be rust and dust proof, impact resisting and dense (EHEDG, 2014).). The wall can be strengthened and protected from damages by e.g. installation of kerbs. The walls must also be non-absorbent and water repellent because of the moist environment in the farm and especially in the rearing room. Therefore, e.g. gypsum material is not recommended, because it is able to absorb liquid in humid conditions. A washable wall is a requirement and it cannot contain any toxic chemicals.

A hygienic wall must be resistant to microorganisms, rodents and insect (EHEDG, 2014). Furthermore, an internal wall needs to be smooth and free from cracks. The joints should be sealed properly. Acceptable wall-materials for cricket rearing is e.g. glazed tiles, prefabricated insulating panels or similar. If the wall is constructed of tiles, the grouting between the tiles must also be durable and non-absorbent. Epoxy is an example of a non-porous and hygienic grouting that can be used around the tiles.

To be able to see damages and dirt, it is good to keep the wall light coloured (EHEDG, 2014). If the wall needs to be painted, mould resistant paint is not recommended for internal walls, due to its reduction in effectiveness over time. Wall-to-wall, wall-to-ceiling and wall-to-floor junctions and corners should be rounded or coved. Notion to horizontal surfaces and sills should also be avoided on the inside due to its difficulty to clean and dirt and dust trapping properties.

6. INTERNAL STRUCTURES

6.1. REARING CONTACT SURFACES

To keep a good hygiene throughout the farm, it is important to use the right material, especially in the rearing room where the crickets are kept. Stainless steel, hot dipped galvanised steel, aluminium, fibreglass, polyvinyl chloride and nylon are examples of approved materials used in food production (EHEDG, 2014). These materials could also be suitable for insect rearing since they are smooth, washable and easy to clean, durable, non-absorbent and impact resistant (the shelves pictured in Figure 9 is an example of a contact surface with a suitable material and design). Materials such as wood are difficult to clean, may pose a contamination risk and should therefore be avoided.

6.2. DOORS

In cricket rearing, doors do not only protect the farm from intruders, but also work as dividers between different activities within the farm, whilst acting as a barrier from contamination of e.g. dust, dirt, pests and insects in the meantime (EHEDG, 2014). Although too many doors may pose a hygienic threat due to an increased risk of contamination. Hence, doors must be hygienically designed to protect the crickets from being contaminated with other subjects that move within the farm.

All doors should be wide and high enough to allow movement between rooms and to prevent objects from bumping into the door or jamb, as cracks poses a hygienic risk (EHEDG, 2014). The contact where the doorframe meets walls and floor also needs to be free of cracks and holes because dirt and pests can easily be harboured on such places. Moreover, the fitting frames must be tight without any gaps at floor-to-door contact being larger than 6 mm. to keep rodents out of the building. Larger gaps can be reduced by placing a rubber strip at the base and replace it when necessary, or by using doors in a small channel, i.e. sliding doors (since dirt can fill the channel, a second barrier and regular cleaning would then be required). It is not recommended to install doors with windows because of the risk of glass breaking. Another threat to microbial growth is inverted U channels at the top of the door, which is a trap for dirt and dust. Avoid these in the farm. If using sliding doors, all gaps between the door and the frame should be closed.

The door should also withstand cleaning and be durable, which means that it should be made of a non-absorbent material, not e.g. wood, which is absorbent and additionally vulnerable to rodent attacks (EHEDG, 2014). The surface material of the door should be:

- light coloured,
- of nontoxic material,
- dense,
- tough and impact resisting – durable,
- rust proof,
- dust proof and,
- resistant to damage by the thermal conditions (e.g. the high temperature and humidity in the room)

5.4.1. EXTERNAL DOORS

External doors should not open directly to the cricket rearing room and should be rodent proof. In addition, the door should be opened outward so that any insects or dirt on the door panel are not swept into the building. To avoid contamination in connection to the external door, there are some methods that could be implemented on the outside as well, e.g. installing a rain roof that can prevent the rain from dripping in and avoiding lightning next to the door, as it attract insects.

5.4.2. INTERNAL DOORS

Internal doors could play an important role in maintaining positive air pressure in the rooms inside the farm. This requires a door with good sealing that fits tightly in the frame (EHEDG, 2014). With a positive air pressure, dirt from the outside will flow out from the room, rather than into the room. The air needs to flow in the right direction and this is achieved by adjusting the pressure in the room. To establish an overpressure, pressure differentials needs to be >3 Pa or air velocities >3 m/s. Personnel entries should be constructed as double doors to allow operatives to wash their hands and change to workwear in the internal “lobby” between the doors.

5.4.3. TRANSPORT DOCKS

When it is time to transport the crickets out from the site, it is recommended to use hatches instead of doors to prevent contamination from outside. If doors are used, it is possible that people step inside the building without washing their hands and changing their clothes. When constructing transport docks in larger food industries, factory floors should always be higher than the outside ground level to create a physical barrier to traffic, both personnel and vehicular (EHEDG, 2014). By using a hatch instead of a door, this barrier will be created automatically. Consider keeping the entrances and exits to a minimum for better control.

6.3. WINDOWS

Allowing staff to see outside is encouraging and could therefore improve productivity. However, house crickets cannot adjust to the variating daylight that takes place in Finland and requires a slightly different photoperiod. The recommended day-night ratio for house cricket is 12:12 or 14:10 (Horppu, Hulshof, & Koskula, 2017). To imitate the ideal photoperiod for house cricket, windows in the rearing room should be avoided. If windows are used elsewhere in the farm, they should preferably be non-openable (EHEDG, 2014). If opened, it could cause contamination by vermin and other animals, such as pets, and also ruin the ventilation system inside the farm. In case non-openable windows cannot be avoided, e.g. if an existing facility with openable windows is transformed into a cricket farm, the windows are to be fitted with insect proof screens, which can be easily removed for cleaning. Furthermore, openable windows must be hooked or locked, because as opened they will disturb the ventilation system installed. The windows should also be constructed to (EHEDG, 2014):

- prevent the build-up of dirt
- be easy to clean
- Ideally double glazed or double windowed to prevent condensation
- protect against breakage (toughened glass or shatterproof plastic)
- be installed at least 1.2 m above floor level
- fit with the frames which are dense, impact resisting, durable, rust proof, non-absorbent, washable, smooth, crevice free (no window frames made of wood)
- if openable, they should open outwards and also allow easy cleaning
- lack windowsills or other horizontal ledges. If it cannot be avoided, outside sills must have a minimum of 60° slope to prevent bird nesting and a slope of 20-45° on the inside window ledge to prevent it from being used as a shelf.

Window screens located within 1 meter from floor level should be reinforced with a 6 mesh, 1.0 mm gauge stainless steel wire to keep out rodents. Screens higher than 1 meter above floor level should be reinforced with an 18 mesh, 0.23 mm gauge stainless steel, nylon or PVC coated fibreglass wire to keep out insects.

6.4. CEILINGS

Ceilings must be constructed to prevent the accumulation of dirt and to reduce condensation and the shedding of particles (EHEDG, 2014). Additionally, ceilings must be:

- light coloured and cleanable
- dense, impact resisting, durable, rust proof and dust proof
- non-absorbent, washable, water repellent and made of non-toxic material
- smooth with sealed joints and free of cracks
- unable to provide harbourage for pests
- resistant to bacterial and fungal growth
- resistant to rodents and insects
- at least 3 m from the floor to help prevent condensation

As for wall and floor junctions, wall and ceiling junctions should also be rounded to facilitate cleaning and prevent dirt accumulation and emerging of cracks (EHEDG, 2014). Ceilings should not support any item or structure, which contains horizontal surfaces. If there is space above the ceiling, the space should be sufficient to facilitate cleaning and maintenance. Perforated or porous ceilings should not generally be used for sound absorbing, i.e. noise reduction, as the material gather dust. Drywall (gypsum) should neither be used in wet and humid conditions because of their porosity.

6.5. INSULATION

Heat losses, condensation and reduction of noise is the major reason to insulate a building (EHEDG, 2014). House crickets thrive in a warm environment, with temperatures around 30°C, which is higher than many other animal farms (Horppu, et al., 2017). For that reason, insulation is a good method of keeping the right temperature inside, especially during cold periods. Although, insu-

lation can be a source of contamination and it is, therefore, important to choose the right material (EHEDG, 2014). Firstly, the wall needs to be non-absorbent and free of cracks. Secondly, insulation should be watertight and checked regularly to ensure it remains dry.

6.6. VENTILATION SYSTEM

In all food handling facilities there must be suitable and sufficient means of neutral or mechanical ventilation (EUR 852/2004). Furthermore, the air needs to be effectively distributed throughout the room space so that no dead zones are created (EHEDG, 2014). If mechanical ventilation is being used, it should:

- have appropriately sited air intakes and extracts that allow appropriate movement through the room space
- be located so that dirty filter elements are removed within an area of lowest hygiene zone classification and away from product streams
- Provide sufficient air changes per hour (between 5-25 changes per hour in medium hygiene area)
- provide airflows that are from clean areas
- remove excessive heat effectively

The air intakes need to be suitably screened against pest access, at least 1 m above internal and external ground levels and away from any possible source of contamination, i.e. air exhaust (EHEDG, 2014). The farm should be operated under slightly positive pressure (2-5 Pa) in order to prevent ingress of unfiltered air.

6.7. HUMIDITY AND TEMPERATURE CONTROL

House crickets thrive in moist environments with a relative humidity around 50-60% and many of the Finnish cricket farms tries to keep a 60% humidity in the rearing rooms because humidity is important for the growth of the crickets (Kukkola, 2018). However, according to Clifford and Woodring (1990) a humidity higher than 50% can be fatal for adult house crickets. Young crickets and eggs need a higher humidity, even up to 70-100% and therefore they are usually kept in sealed boxes separated from older crickets (Horppu, et al., 2017). Nevertheless, EHEDG (2014) recommends that the relative humidity in the conditioned air is below 55%, thus fungal (moulds and yeasts) as well as bacterial growth can be prevented.

As earlier mentioned, house crickets thrive in warm environments with temperatures up to 30°C with an optimal temperature of 28°C (Horppu, et al., 2017). Temperatures above 30°C shortens the cricket's life cycle and if temperature reaches 38-40°C, mortality can occur in up to 100% of the population. Therefore, it is important to control the temperature in the rearing room (EHEDG, 2014). The temperature can be adjusted using radiators, but these should be properly installed with enough surrounding space to enable maintenance and cleaning of the radiators, as dust and airborne particles poses a risk for contamination.

Mechanical ventilation can be used to add or remove both heat and humidity. Especially in larger cricket farms, mechanical ventilation and climate control is an efficient way of achieving a balanced humidity, temperature and air flow all year round, regardless of the outside climate (Munters, 2018a). The technology behind climate control is a desiccant drying wheel (rotor) that removes moisture from the outside air, warms it up and then drives the warm humid air back into the room where it is needed (Munters, 2018b). This technology can then be controlled to keep an even climate inside the rearing room. By using this mechanism, the energy efficiency in the farm will be optimized and consequently cost-effective (Munters, 2018a). Furthermore, an air filter is needed to capture dust particles and the majority of microbes that occur in the air that flows into the farm (Wirtanen et al., 2002). To enhance the efficiency and cost-effectiveness of the filter, three different filters can be used, where the primary filter collects the largest air particles while the second filter remove particles from the air to a level needed in the process. The tertiary filter ultimately offers the best protection from unwanted air particles.

6.8. STAIRS

If stairs are needed in the rearing facility, they need to be kept hygienic and easy to clean, just like other equipment. The major requirements are met when crevices, ledges and voids, which could harbour dirt and microbes, are avoided (EHEDG, 2014). Furthermore, stairs should be encased if placed above the cricket rearing, to restrict any dirt dripping from the operative's footwear (see Figure 9). Supporting and framing structures should be designed to eliminate as many free ledges as possible and minimize the accumulation of dirt and dust.

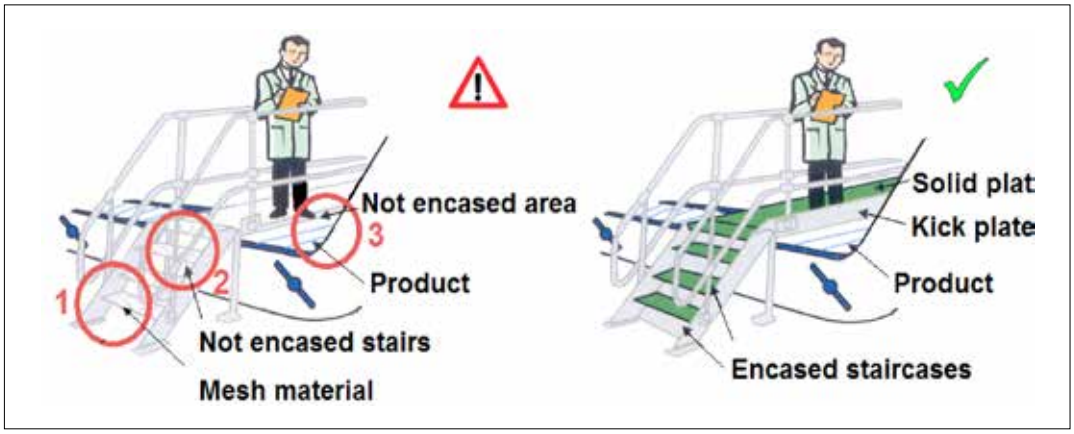

Figure 9. Encased staircases showing how the encasing can protect against dirt dripping onto the process below the stair (EHEDG, 2014).

Structures made of circular tube, i.e. handrails, should be welded leaving no openings and all open ends should be sealed e.g. with welded plates. It is recommended to use latticed metal plates instead of open metal grids, since latticed metal-plates are easier to clean.

7. SERVICES

7.1. GENERAL HYGIENE

The keeping and treatment of the specific animals needs to be considered when rearing. The rearing area needs to be sufficiently spacious, protective, light, clean and safe and otherwise appropriate taking into account the needs of each animal species and minimizing the risk of an animal escaping (Evira, 2018b). Farmers can use the HACCP approach in order to eliminate the hazards or reduce them to acceptable levels in insect farming (EFSA Scientific Committee, 2015). The HACCP approach can be made specific depending on the farming and production techniques being used. All farmers need to test for pathogens and make sure that the limits for antibiotics, pesticides and other contaminants are below the legislative maximum. Clean water is to be used throughout the production and equipment disinfected with approved products between batches.

7.2. WATER QUALITY

All food handling sites must have an adequate supply of hot and cold water, which can be used when necessary (EHEDG, 2014). In primary production the water is used as drinking water for the insects, for cleaning and cooling of primary products and for cleaning and rinsing of surfaces, equipment and tools (Evira, 2018b;EFSA Scientific Committee, 2015). No foreign matter, including parasites and microorganisms, which could endanger the safety of the primary products, may occur in the water. Sewage and liquid disposal waste should be properly conveyed allowing the water to drain effectively (EHEDG, 2014). These actions also minimizes the risk of crickets escaping into the nature. Furthermore, areas dedicated for dry product production should as far as possible be designed without water systems to prevent threats due to leakage and thus prevent microbial growth.

7.3. PIPES

All pipework, ventilation points and other services should be placed with an appropriate distance from the wall or ceiling, to minimize dirt accumulation and to facilitate cleaning (EHEDG, 2014). If pipework needs to pass through a wall, ceiling or floor, it should be mounted in sleeves, which is a length of pipe built into floor or wall construction to provide an opening where pipes or cables can pass. When several pipes penetrate the floor, the cleanability can be improved by surrounding the pipes with a curbed floor (Figure 10). The curb must be completely closed with a cover leaving no gaps around

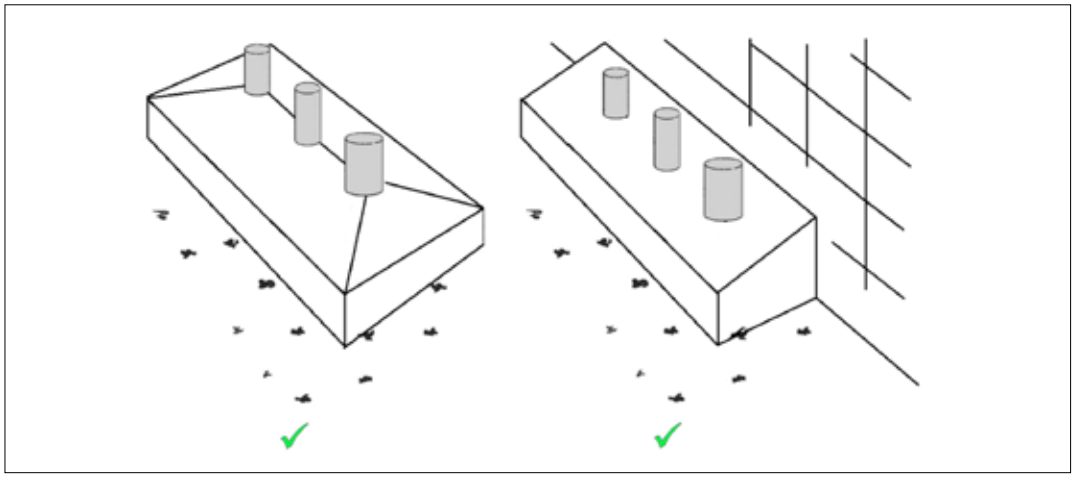

Figure 10. Surrounding of pipes in a curbed floor (EHEDG, 2014).

the penetrating piping. The piping network should have clearances of 100 mm between each pipe, 50 mm from walls and floor and 250 mm free space left between parallel rows to avoid residue collecting points.

Pipes should run in separate accessible gangways (pipe trains) and enter the process area through the ceiling (EHEDG, 2014). If this is not possible, open trays that are fixed to the walls or columns close to the ceiling should be used. These should be designed hygienically to minimize presence of horizontal ledges, crevices or gaps, where inaccessible dirt can accumulate. Dead areas in the potable water system, i.e. pipes not in use in the water distribution flow, support microbial amplification i.e. *Legionella*. Therefore, dead legs should be avoided. If unavoidable, these legs should be as small as possible. Condensation on piping should be prevented through e.g. isolation or appropriate sloping and draining drip trays.

7.4. ELECTRICAL INSTALLATIONS

All cables should be installed so that they are easy to clean (EHEDG, 2014). Vertical cable trays are preferred to horizontal installations. In case horizontal surfaces cannot be avoided, they must be sloped 45 degrees. Threads on cables are difficult to clean and should not be used. Furthermore, all cables must have sufficient distance to each other to enable for cleaning and the cables shall be installed in a single layer. Bundle of cables must not be used due to moist and thus fungal growth inside the bundles. A conduit can be used to enclose the cables but they need to be sealed all the way as open ends can collect dirt, moisture, microorganisms and other pests.

7.5. LIGHTNING

All areas where raw materials are kept and food is farmed, produced or stored, as well as equipment or utensils are cleaned, must have adequate natural and/or artificial lightning for the activities conducted (EHEDG, 2014). Lightning of poor colour gives marked distortion of the original colour. The lightning should either be suitably sealed to the ceiling or wall or installed with adequate space between lightning and wall/ceiling to prevent dust accumulation. The installation should also enable cleaning and maintenance. If the light is not sealed to a ceiling or wall, the lightning should have a sloped body of 45 degrees to enable cleaning and prevent dust accumulation (Figure 11). Light sources should not be placed right above rearing process, to prevent both broken lamps and other objects from falling into the insect boxes. However, light sources should be enclosed tightly i.e. water-, dust- and insect-tightly.

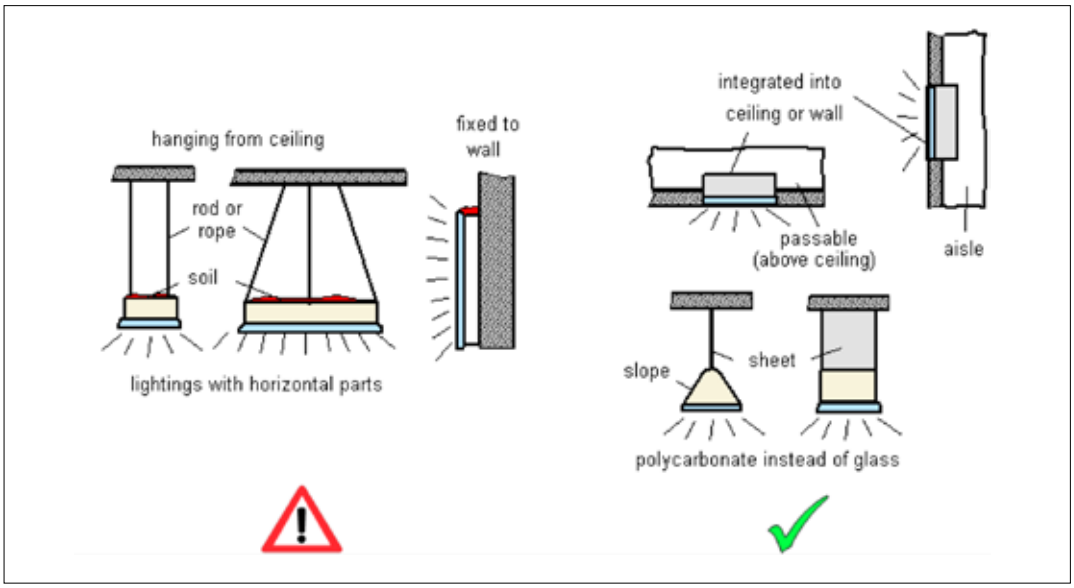

Figure 11. To the left are examples of unhygienic lightning installation and to the right proper hygienic installation of lightning (EHEDG, 2014).

7.6. FOOD AND SOLID WASTE

The substrate or other materials used in insect farming should not endanger the food safety. They must be of good quality and clean, when used in rearing (Evira 2018b). Therefore, the egg cartons commonly used as growth substrate in insect rearing cannot be reused (neither in the egg industry nor by the insect farmer); they should be sent as garbage to the waste collection or burnt.

7.6.1 WASTE AS FEED FOR INSECT

It is possible to rear insects on organic side streams and in that way add value to the biowaste (van Huis et al., 2013). These side streams could consist of by-products from food industry, such as leftovers from vegetables, fruit or grains (Evira 2018b). It is not possible to feed the insects with animal originated by-products or manure. Nor is it allowed to use human food leftovers as feed. However, it is possible to use plant-based leftovers from food service or restaurants that have not been served. Any spoiled food (e.g. mouldy vegetables) is not suitable as feed.

7.6.2 BY-PRODUCTS FROM INSECT FARMING

The by-products that appear in insect farming are parts from the insect, insects that have died naturally, insect eggs, maggot skin and pupas, together with excrement or frass (Evira 2018b). Frass is the excrement of insects, which could also contain substrate, uneaten feed, insect parts, or naturally dead insects. The rearing substrate must be properly heated before throwing it away or burnt, to prevent any potential remaining eggs from hatching in the nature. Composting is an effective way of killing remaining insects or its eggs as well as reducing the microbial hazards of raw manure and other substrate before emptying the waste. Composting treatment reaches high temperatures thus killing most of the pathogens. Adequate provision must be made for storage and disposal of fresh and aged insect feed as well as dead or harvested insects.

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