Smallholder Cricket Rearing in Cambodia

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Note from the editor

The original of this manual was written in Khmer and addressed Cambodian farmers. In this way, it works with terms, definitions, and procedures that are common knowledge in Cambodia, but not necessarily outside the country. When deemed necessary, adaptions to an international public were made. This is why the English version differs in some parts from the Cambodian original.

Dr. Nils Th. Grabowski

Introduction

Smallholder cricket rearing is attractive among Cambodian farmers because it provides a good alternative activity that farmers can get extra income beside agriculture and animal rearing activities. In addition, cricket rearing (and consuming them) also combats malnutrition providing valuable nutrients (especially protein), e.g. to children under 5 years old whose body weight is under standard (Unicef, 2017) and mothers aged between 15-49 years. In this case, malnutrition translates especially into the shortfall of animal-derived foodstuffs (including edible insects [e.g. crickets]) that children and mothers cannot access.

This document was written for the IFNext project, and was based the experience from different studies and demonstrations with farmers on cricket rearing by Dr. Miech Phalla, director of Livestock Development for Community Livelihood Organization (LDC), formerly named "Center for Livestock and Agriculture Development (CelAgrid)". These so far unpublished studies included, among others, the effect of yield on using different number of cardboard egg cartons per pens, the effect of yield on using different egg bowls per pen, the comparison of fresh yield of red and black crickets (for the cricket names, see section 1), and the effect of broad leaves plants and grass types fed as basic diets for red and black crickets. It will provide basic knowledge and simple ways to rear crickets which farmers in rural areas in Cambodia can do because most of materials and feed are available to find in their region.

Advantages of cricket rearing

- A year-round production and a short production cycle (30-45 days) is possible.
- They can eat a wide range of feed sources.
- Crickets convert feed efficiently into weight gain (Van Huis *et al.*, 2013).
- They consume less water and need little space (Van Huis *et al.*, 2013).
- Rearing affects the environment less and carries less risks of transmitting infections to humans, livestock, and wildlife, compared with mammals and birds (Van Huis *et al.*, 2013).
- Crickets provide valuable nutrients, especially proteins, vitamins, minerals and fats (Moreki *et al.*, 2012; Wang *et al.*, 2005; Finke, 2002; Barker *et al.*, 1998; Finke *et al.*, 1989; Nakagaki *et al.*, 1987; DeFoliart *et al.*, 1982).
- They also provide manure and feed residues for fertilizers.
- Harvesting of wild crickets (which may affect natural populations, impacting on the environment) can be reduced.

Potential of cricket rearing

- Farmers can access crickets from the wild and adopt them to captivity, starting thus their own farm.
- A large array of feed resources is usually available at the farms anyway.
- Material is available in the region.
- Compared with other livestock, crickets are easy to rear.
- Less investment for starting cricket rearing is necessary.
- Crickets are consumed whole in Cambodia (i.e., there is no need for a further processing), and there is a high demand for local and export markets.

Section 1: Cricket species

There are different cricket species, but most potential for smallholder cricket rearing lies in local ones such as the Cambodian (*Teleogryllus mitratus*[1]) and the Mediterranean field cricket (*Gryllus bimaculatus)*. Locally, they are known as the "red" and the "black" resp. "Daek" ("iron") cricket, respectively, and this terminology will be retained. The full lest of local cricket species in Cambodia that can be harvested from the wild is presented in Table 1. However, successfully farmable cricket species at the present time are only two species *Teleogryllus mitratus* and *Gryllus bimaculatus*, while others are on the test.

Why do we need to select local breeds?

- Available and easy to catch from nature (Figures 1 and 2)[2]
- Easy breeding
- Tolerant with diseases
- Tolerant with local environmental conditions (temperature and humidity)
- Less expensive compared with imported species in terms of transportation and waiting time to order crickets' eggs from abroad, in case of a new start-up or when replacing the breeding colony.
- We can replace farms' crickets easily from the wild, if crickets in the farm colony should die.

How can we obtain local crickets to rear?

- Catch from the field under dead tree leaves/palm leaves or wood by hands or
- Use light to trap crickets at night
- Buy bred ones from other farmers

Table 1: Cricket species that can be caught from nature by light trap at night

Species	Khmer name*	English name
Acheta domesticus	ចង្រិតស (“white cricket”)	House cricket
Gryllotalpa africana	ខ្ចៀ (“crawler under the ground”)	African mole cricket
Gryllus bimaculatus	ចង្រិតដែក (“Daek cricket”)	Two-spot cricket (Mediterranean field cricket)
*Teleogryllus mitratus***	ចង្រិតក្រហម (“red cricket”)	Cambodian field cricket
*Trabinskiellus portentosus****	ចង្រិតដូង (“coconut cricket”)	Short-tail cricket (Big head cricket)

* There are different name each species in Khmer by region
** Previously known as "Teleogryllus testaceus"
*** Previously known as "Brachytrupes portentosus"

[1] Known previously as "Teleogryllus testaceus"
[2] Cambodian light traps consist of a frame, a white opaque plastic foil, a light source, and an open container filled with salted water. At dawn, the light is switched on, insects head to the light, collide with the plastic foil, and fall into the water. Late at night, the traps are controlled by the operators, and collect the edible species.

Figure 1: Trapping crickets with light at night and picking them from the light traps

Figure 2: Sorting the catch

(*Images: Joe Garrison © [2005], quoted by Münke, 2012)*

1.1. Local cricket species

1.1.1. Red cricket *(Teleogryllus mitratus)*

The red cricket (Figure 3) has a medium-sized body and can be harvested at an age of 40-50 days (average 45 days; Figure 4) from hatching. Average adult crickets have a body weight of approx. 0.9 gram at harvest. Red crickets like to live in the fields such as rice fields or chamkars[3]. Red crickets are tolerant to diseases, unclean housing and have a low mortality. They can be reared at high densities and can sell at a price of 3 USD/kg. Most cricket farms remain successful when they rear red crickets.

Figure 3: Red cricket (*Teleogryllus mitratus*): male (left) and female (right); note that the central "thorn" at the hind tips of the bodies consist of extensions of the forewings (so-called tegmina) in both sexes, but adult females have an additional spur, the ovipositor, which is longer than the tegmina.

[3] In contrast to a rice paddy, a chamkar is a traditional Cambodian raised bed plantation for vegetables.

Life cycle of red cricket at 45 days.

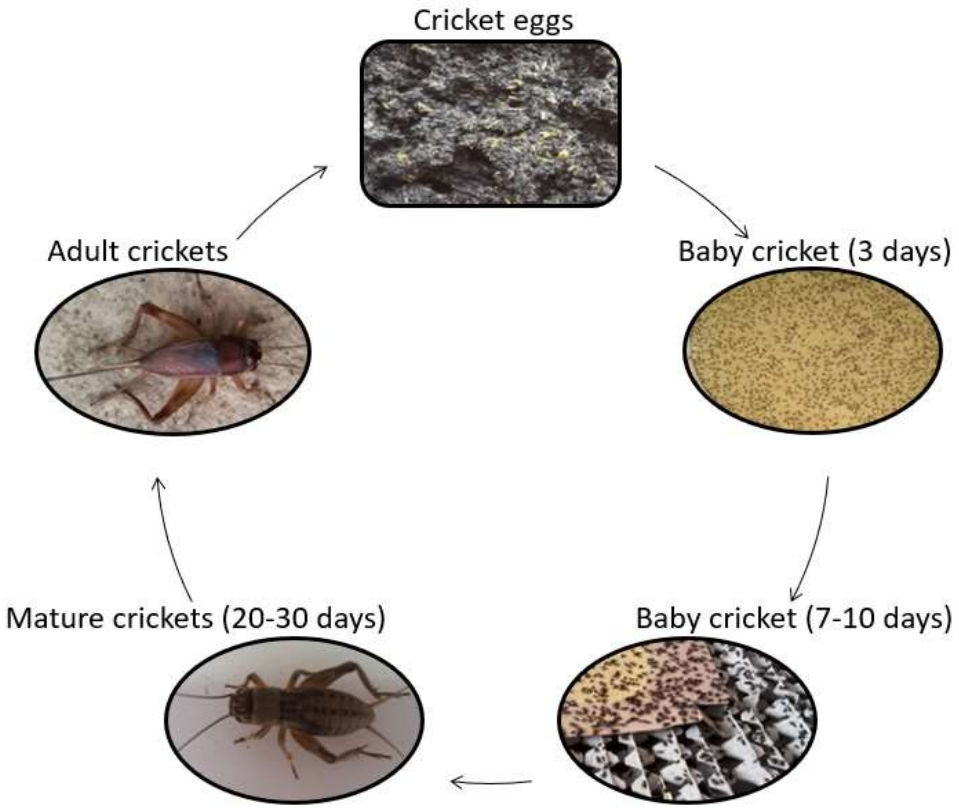

Figure 4: Life cycle of the red cricket from egg to adult, taking 45 days to harvest.

1.1.2. Black (Daek) cricket *(Gryllus bimaculatus)*

The black cricket (Figure 5) has a bigger body than the red cricket has. Average body weight in the adult stage is 1.13 gram at harvest and can be harvested at the age of 30-40 days (average 35 days; Figure 6). Black crickets also like to live in the rice fields. Black crickets can also be reared at a high density and the market price is 4 USD/kg. However, black crickets are not so resistant to diseases and may display a high mortality (up to 100%). The symptom of a typical disease is an enlarged belly (water accumulation), slow motions, loss of appetite etc., possibly a viral infection (Baculovirus). Most farms turn unsuccessful after one to two years if they rear black crickets.

Figure 5: Black cricket (*Gryllus bimaculatus*): male (left) and female (right); note that the central "thorn" at the hind tips of the bodies consist of extensions of the forewings (so-called tegmina) in both sexes, but adult females have an additional spur, the ovipositor, which is longer than the tegmina.

Figure 6: Life cycle of the black cricket from egg to adult, taking 35 days to harvest.

To help in decision-making, Table 2 sums up the advantages and disadvantages of red and black crickets, while Table 3 contains the basic productive data.

Table 2: Advantages and disadvantages of local species

	Red cricket (*Teleogryllus mitratus*)	**Daek cricket (*Gryllus bimaculatus*)**
Advantages	• Tolerant with diseases • Medium body (compared with white and black crickets) • High market demand • Tolerant to unclean environment in rearing area	• Short production cycle • Large body • High market demand • High price • Produces more eggs • High rate of eggs' laying and hatching
Disadvantages	• Low price compared with black breed	• Less tolerant with diseases, may result in colony collapse after several production cycles • Less frequent in nature • Replacement after several production cycles is needed

Table 3: Basic productive data of red and black crickets

	Red cricket (*Teleogryllus mitratus*)	**Black cricket (*Gryllus bimaculatus*)**
Production cycle from hatching to day of harvest [days]	40-50	30-40
Body weight/cricket (harvest, [g])	0.9	1.13
Tolerant with diseases	Medium	Poor
Survival rate [%]	50	40*
Market demand in Cambodia	Medium	High

* May be decreasing after some production cycles

1.2. Imported crickets

Empiric evidence indicates that cricket farms in Cambodia have been importing animals from Thailand and Vietnam in form of eggs for the last 10 years because they are easy to transport to the country. Those breeds are white crickets (*Acheta domesticus),* Jamaican field crickets (known locally as "imported red crickets"; *Gryllus assimilis*[4]*)*, and black crickets *(Gryllus bimaculatus).* Table 4 and Figure 7 sum the differences between local red crickets (*Teleogryllus mitratus*) and imported red crickets (*Gryllus assimilis*) as noted by the breeders.

[4] Currently, there is a taxonomic debate going on. *G. assimilis* is a cricket species thought to be kept as a feed insect species (for pet animals such as reptiles, amphibians, birds etc.) worldwide. However, the original population in the Americas seems to consist actually of several species which differ mostly in terms of chirping and genetics rather than morphology. It is thought that the pet feed species is in fact *Gryllus locorojo* rather than *G. assimilis.*

Table 4: Different between local and imported red cricket species

Local red crickets (*Teleogryllus mitratus*)	Imported red crickets (*Gryllus assimilis/locorojo*)
• Low inbreeding rate • Active • High hatching rate • High survival • Big and long back legs • Big body • Tolerant with temperature and humidity • The female cricket has a long egg tube	• High inbreeding rate • Not so active • Low hatching rate • Low survival rate • Small and short back legs • Small body • Not tolerant with temperature and humidity • The female cricket has a short egg tube

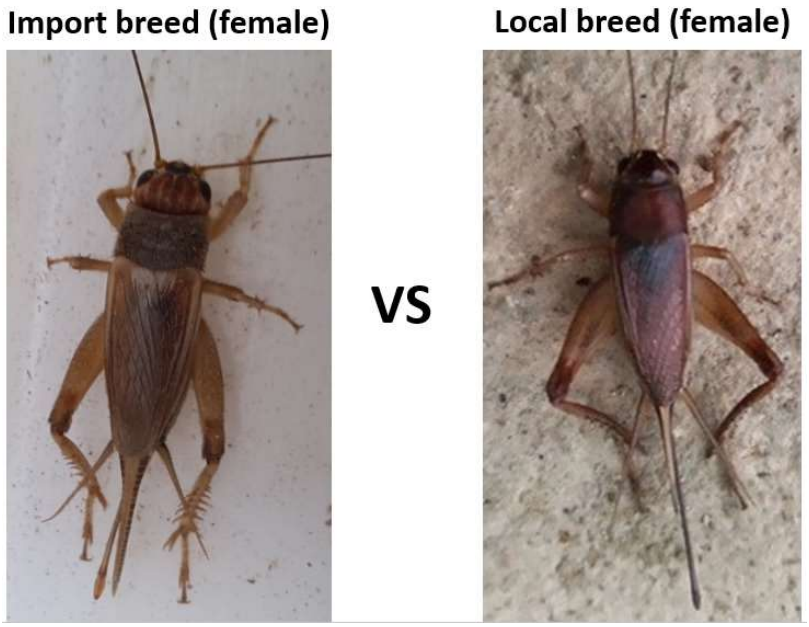

Figure 7: Differences between import (*Gryllus assimilis/locorojo*, left) and local red crickets (*Teleogryllus mitratus*, right)

1.3. Breeding

Cricket production relies heavily on providing "fresh blood" to the colony (see next section). In a small concrete cylinder (tube) pen, three to four generations can be raised from an unchanged colony, but then, a different strain should be included to avoid inbreeding. Farmers can buy crickets resp. their eggs from other farms for breeding. To keep a good quality and avoid inbreeding crickets, two options are recommended:

- **Option 1: Rotational breeding in concrete tubes**
    - Generation 1: Eggs in concrete tubes A, B and C
    - Generation 2: Take eggs in tube A and join with eggs in tube B
    - Generation 3: Take eggs in tube A and join with eggs in tube C
    - Generation 4: Take eggs in tube B and join with eggs in tube C
    - Generation 5: Take eggs in tube A, B and C exchange with other farms

- **Option 2: Enhancing farm cricket strains with wild-caught ones**
  - Catch crickets from the wild at night using light traps (see Figures 1 and 2).
  - Select healthy adult wild-caught crickets to be reared together in the same pen with adult farmed crickets.
  - Allow at least 7 days of quarantine for wild-caught crickets in order to recover from stress after catching and transporting from the field to the pens.
  - Wild-caught crickets and farmed crickets should be the same age.
  - Let wild-caught and farmed crickets' mate to collect eggs for hatching.
  - Start a new generation with eggs from farmed and wild-caught/farmed crickets in a new pen.

1.4. Inbreeding

Inbreeding is a constant menace for cricket farms that use the same parent stock from year to year. It will make the animals weak and leads to slow growth and low production. Inbreeding can occur during a third or fourth production cycle, especially at farms that rear crickets in small pens. Thus, to avoid inbreeding, the owner needs to change the strain during each third or fourth production cycle.

1.5. Development from eggs to adult crickets

1.5.1. Eggs

The amount of laid eggs depends, among other factors, also on the species. Every two to three days, white crickets lay 50 to 100 (Fluker Farms, s.a.), while red crickets 150 to 400 eggs. At an ambient temperature at 35 °C, one female white cricket can lay between 1200 and 1500 eggs in one month (Patton, 1978).

To make the animals oviposit, plastic bowls containing moist biochar are placed in the pens with adult crickets (Figure 8) and retired in time (see section 1.5.2) for incubation that allows the eggs hatching at the same time for the next generation.

Figure 8: Plastic bowl with biochar used for crickets laying eggs

Figure 9: Cricket eggs in biochar

1.5.2. Egg incubation

Hatching rates of cricket eggs are variable, depending on humidity and temperature. According to the recommendations of Fluker Farms (s.a.), the good hatching humidity is from 80 to 90%, and hatching will occur within 7 to 15 days, depending on the temperature (e.g. 13 days at 30.0 ºC: 13 days and 23 days at 23.3 ºC: 23 days). The actual values will depend on the local conditions and the farmer's experience.

Hatching rate of white cricket's eggs can range from 55 to 68%, depending on the ages of parent stock (Clifford and Woodring, 1990)

Figure 10 summarizes the steps of preparing the incubation.

Figure 10: Steps for preparation of cricket eggs' incubation

1.5.3. Baby crickets and skin moulting

At 28.8 to 30.0 ºC, baby crickets take six weeks to reach adults stage. In order to grow, they need to shed their skin periodically ("moulting"). The frequency of moulting in baby crickets is variable and depends on the temperature. Only baby crickets (nymphs) of house cricket moult, the adults (imagines) do not.

- 30.0 ºC: shed of skin 8-9 times (Clifford and Woodring, 1990)
- 23.3 ºC: shed of skin 10 times (Fluker Farms, s.a.)

Right after shedding their skin, baby crickets have soft, milky-white bodies (caution while handling them!) but the skin will become as normal (harder, typical coloration) within 24 hours. Once nymphs reached the adult stage, moulting (and therefore growth) stops. It is then that the cricket sex differences become apparent. For the female cricket, the short wings sprout and the ovipositor ("egg tube") may be seen, while in the male cricket, there is no egg tube (Figures 3, 5, and 7). See also the Figures 11 to 13 (imagines).

Figure 11: Female baby cricket shed the skin (see the ovipositor)

Figure 12: Male baby crickets shed the skin (see the absence of ovipositors)

Figure 13: Imported red crickets (*Gryllus assimilis/locorojo*) shed the skin to maturity (40 days old, entering the imago phase), female (left), male (right)

1.5.4. Adult crickets

The adult (imago) stage is the reproductive stage (Figure 14). Adult crickets live for two to three months and can mate several times, while some die after breeding. Adult crickets (female or male) can fly for only the first two days after the last shed of skin.

- The female cricket does not lay eggs without breeding or if there is no suitable place for laying eggs.
- Crickets can mate after three or four days after the last shed of the skin and lay the eggs in next eight to ten days.

Figure 14: Black (left) and red (right) crickets; adults are marked in red squares, nymphs in yellow circles

Section 2: Pen types

There are two types of family cricket farms that have been successfully implemented a) plastic containers (140 liters) and b) concrete tubes (or concrete cylinder pens with the size of 0.8 m diameter), leading to similar yields. In addition, concrete block pens in the shape of rectangular fish tanks are suitable to use for large scale cricket rearing. A typical set consisting of three units is presented in Figures 15 and 17.

2.1. Plastic containers

- Removeable plastic containers (140 liters): 3 units (a set)
- Cricket production: 4 kg/container resp. 12 kg in 3 containers
- Yield: 4 kg/m² (size of the area where containers are locating)

Figure 15: Two sets of plastic containers of three units each

When using containers placed onto a rack, it is a good idea to place dishes containing water or other, non-toxic liquids around the legs of the racks (Figure 16). This helps keeping the pens free from ground-dwelling arthropod predators such as ants.

Figure 16: Dishes filled with liquid at the legs of containers to protect the crickets from ground-dwelling predators

2.2. Concrete tubes (or concrete cylinder pens)


- Concrete cylinder pens: 3 units
- Diameter: 0.8 or 1 m
- Height: 0.5 m
- Cricket production: 4 kg/cylinder pen resp. 12 kg in 3-cylinder pens
- Yield: 4 kg/m² (size of the area where containers are locating)

Figure 17: Concrete cylinder pens

While the basic types of cricket pen generally does not affect the crickets yield at harvest, there are other factors that do so, i.e. climate (temperature and humidity), feed, and the quantity and quality (*cave* carry-over of toxic substances) of materials placed inside the pens to provide a place where crickets can rest, stay and hide themselves during development stage, e.g. cardboard egg cartons and other materials used for this purpose.

2.3. Equipment needed for three concrete tubes

While boxes can be equipped relatively easily with the egg cartons, feed and water trays etc., concrete tubes must be adapted to serve as cricket enclosures.

For a concrete tube set as a model for farmers' practice, we need:

- 3 concrete tubes with diameter of 0.8 to 1.0 m and a height of 0.5 m.
- 1 bag (50 kg) cement and sand (0.5 m³) for constructing the base for placing concrete tubes, and construct small moat (size 15 cm around the tubes) filled with water to prevent the entrance of predators (ants mainly)
- Cardboard egg cartons:
  - 72 cartons for a 0.8 m tube (24 cartons per tube)
  - 99 cartons for a 1 m tube (33 cartons per tube)
- 2 covers of containers used for offering feed and water (1 for water and 1 for feed)
- 1 old motorbike tube for tying the net-cover, and several bamboo sticks use as bases for preventing cardboard egg cartons from decaying.
- 1-piece mesh/veil size:
  - 1.0 x 3.0 m for a 0.8 m tube
  - 1.2 x 3.6 m for a 1 m tube
- plastic tape to prevent cricket escape

2.4. Installation and equipping

The steps to adapt concrete tubes to cricket farming are summarized in Table 5 and illustrated in Figures 18 to 24.

Table 5: Checklist to set up a concrete tube set

Step	Details
Steps to build a set concrete pen	• Scrape the sand to make bottom 5 cm thick of an area 1.4 m x 3.5 m per set of 3 concrete tube (1m) • Put the concrete tube on the sand and keep 5 cm from each tube • Mix cement and sand to make concrete 2 cm thick in the base of all 3 concrete tubes • Make drainage (small moats) bins around all three tubes
Equip with materials	• Put plastic inside concrete tube neck (Figures 20 and 21). • Cut and arrange bamboo sticks as a base for the egg cartons (Figure 22). • Put the egg cartons onto concrete tube on bamboo sticks (Figure 23). • Put egg bowls for incubation (Figure 24). • Place the water and feed trays on the egg cartons (Figure 25). • Cover the concrete tube with the net-cover mesh and ty using motorbike tube tightly (Figure 26).

Figure 18: Apply plastic tape around the concrete tube neck to prevent crickets to escape

Figure 19: Apply two to three plastic tape layers to make sure crickets cannot escape

Figure 20: Arrange the small bamboo on the bottom of tube to insert the egg carton

Figure 21: Chicken eggs carton put onto the small bamboo sticks

Figure 22: Place the egg bowls for incubation on top of the egg cartons

Figure 23: Place the water and feed trays onto the chicken egg cartons

Figure 24: Images on how to cover the tanks tightly with the mesh applying a good pull

2.5. Technical data for rearing crickets using a set of three concrete tubes

To rear crickets in a concrete tube set (1.0 x 0.5 m in height) with three units, …

- …use 4 eggs bowls per tube.
- …use egg cartons as a hiding space for the crickets and discourage escaping.
- …use feeds that available in the rearing area.
- …mix chicken/duck feed and cassava leaf and plus other foliage/plants.
- …harvest at 35 days for black cricket to 45 days for red cricket from hatching for economical benefit.
- …yield should be 2 to 4 kg (fresh weight) per tube.

Section 3: Feed, feeding and water

3.1. Feed types

Being omnivorous, the crickets can eat almost everything, which makes it easy for farm owners to find different feed types for crickets. Concentrate feed from chickens, ducks or pigs are commonly used for feeding crickets. But if the cricket owners used 100% of concentrate from feed manufacturers for crickets, their farm may be in economic danger as this food is expensive. In addition to concentrate feed, farmers have a wide selection of low-cost feed like high-quality forage that is available in their region including

- plants that grow in the fields or chamkars, along roadsides, canals, ditches, grasslands, etc.,
- vegetables, fruits and other root/tubers,
- industrial residues or by-products (residue from mung bean sprout production, from soybean juice production, and beer brewery) and/or
- agricultural residues or by-products (leaf, cassava, rice bran, etc.).

Figures 25 to 36 present some feedstuffs used in cricket production. Table 6 lists the typical feed plants with their Khmer names, while Table 7 provides nutritional information on these plants. Nutritional values vary throughout literature since plant composition varies with the soil, the growth phase, and the part of the plant, among others.

3.1.1. Concentrate feeds and residues from agricultural and industrial by-products

Figure 25: Chick feed

Figure 26: Duck feed

Figure 27: Rice bran

Figure 28: Residue from beer brewery (spent grain)

Figure 29: Residues from mung bean (*Vigna radiata*) sprout production

Figure 30: Cassava foliage (*Manihot esculenta*), residue from cassava plantation

Figure 31: Water spinach (*Ipomoea aquatica*)

Figure 32: Redflower ragleaf (*Crassocephalum crepidioides*)

3.1.2. Leaf plants

Figure 33: Fringed spiderflower (*Cleome rutidosperma*)

Figure 34: Asian spiderflower (*Clemone viscosa*)

Figure 35: Asiatic dayflower (*Commelina communis*)

Figure 36: Alligator weed (*Alternanthera philoxeroides*)

Table 6: Typical plants used in Cambodian cricket nutrition I: rearing

Family	Species	Khmer	English	Used part(s)
Amaranthaceae	*Amaranthus spinosus*	ផ្ទីបន្លា	Spiny amaranth	Whole young plant
Asteraceae	*Crassocephalum crepidioides*	ស្ពៃទឹក	Redflower ragleaf	Whole young plant
Cleomaceae	*Cleome rutidosperma*	មមាញ់ខ្មោចជ្រូក្រហម	Fringed spiderflower	Whole young plant
	Cleome viscosa	មមាញ់ខ្មោចជ្រូលឿង	Asian spiderflower	Whole young plant
Commelinaceae	*Commelina communis*	ស្លាបទា	Asiatic dayflower	Whole young plant
Convulvolaceae	*Ipomoea aquatica*	ត្រកួន	Water spinach	Stems and leaves
Euphorbiaceae	*Manihot esculenta*	ត្រួយដំឡូងមី	Cassava	Foliage

Table 7: Proximate composition [%] of the plants used for rearing crickets (Achidi et al., 2008; Adjatin et al, 2013; Agbede et al., 2012; Banerjee & Matai, 1990; Barathidhasan et al., 2007; Chhay, 2012; Ezeabra & Nwafulugo, 2015; Fasuyi, 2005; Ikhajiagbe et al., 2007; Khan et al., 2013; Lee et al., 1994; Little, 1979; Mansoori et al., 2017; Payne, 1990; Rjeibi et al., 2017; Singh et al., 1982; Suthari et al., 2017; Umar et al., 2007; Uraku & Uraku, 2018); as various sources are presented, data is shown as ranges between the highest and lowest values, if possible.

	Moisture content	Dry matter base			
		Ash	Crude protein	Crude lipid	Crude fibre
Trianthema portulacastrum	74.00	27.96 – 35.42	9.51 - 21.53	1.32 – 2.70	17.09 - 43.82
Alternanthera philoxeroides	85.50 - 91.1	10.50 – 13.90	6.40 - 25.90	1.40 - 4.70	7.50 - 22.30
Amaranthus spinosus	59.95 – 64.87	18.28	29.22	10.59	10.71
Crassocephalum crepidioides	86.75 – 86.83	19.01 – 19.03	27.12 – 27.14	3.45	8.17 – 8.19
*Cleome viscosa**	89.98 – 93.06	3.51 – 9.00	1.97 - 13.54	0.09 - 4.29	6.44 – 22.11
Commelina communis	88.08	25.08	24.50	18.71	25.92
Ipomoea aquatica	72.54 – 91.88	10.03 – 14.10	6.30 ± 0.27	2.60 - 11.50	15.50 – 18.02
Manihot esculenta	74.00 – 78.9	3.48 - 13.28	23.50 – 37.38	6.31 – 15.60	11.50 – 19.54
Cynodon dactlyon	62.79 - 87.40	9.78 - 10.20	9.20 - 13.20	2.05 - 5.30	32.00 – 35.96

*variation due to separate analysis of leaves and stems in Ezeabra & Nwafulugo, 2015

When collecting the feed plants, special care must be taken that the plants are clean and grow in areas where no contaminants (insecticides, pesticides, etc.) have been applied, as there is the risk of carry-over of these substances to the human via the ingestion of farmed crickets.

3.2. Feeding

Feeding fresh plants should be provided daily with sufficient amounts and mixed varieties of plants to ensure adequate nutritional supply. In particular, feeding of any type of concentrate feed or feed containing more than 80% dry matter should be given one in every two days in sufficient quantity to save some time in feeding. In case of concentrate feed (MD contents more than 80%), some cricket farm owners wet their feed before feeding to crickets, while others don't. Grinding or wetting the concentrate feed before feeding to cricket is recommended to avoid feed waste. However, this method need to be smart on calculation how much crickets in a pens need per day, otherwise, the refusal feed will spoil. Feeding is placed in the feed tray, especially when using wet feed (Figure 37). As an alternative to feed trays, chicken feed can be placed on carton or cleaned cement bags (Figure 38).

Figure 37: Whole young fringed spiderflowers (*Cleome rutidosperma*) on a feeding tray and water tray with rubble to prevent animals from drowning

Figure 38: Clean cement bag (left) and box carton (right) used as feed trays

3.2.1. Feeding baby crickets

On the first day of hatching, the owner has to provide a shallow feed tray, strong paper, or a clean cement bag to allow baby crickets to eat easily. Normally, they feed chick concentrate feed (in Cambodia with typically 21% protein) and owners also can add cassava leaves and water spinach to crickets under the age of 20 days, but some cricket owners use commercial duck concentrate feed for crickets from the first day on. Additional water can be provided by using a sponge (Figure 39) for baby crickets less than 10 days-old.

Figure 39: Layouts for a rearing pen during rearing babies: general (left), detail of supplying water with a sponge (right)

3.2.2. Feeding mature and adult crickets

Feeding adult crickets is basically not different from feeding baby crickets. Mixing chick feed with 21% protein with chicken feed with 14% protein for crickets older than 20 days is a common practice by cricket farmers. Some cricket owners use high protein content concentrate feed for pigs mixed with rice bran (1-part feed mix, 3 parts of rice bran) for feeding crickets older than 20 days. When using plants for adult crickets, it is recommended to mix different plants for ensuring enough nutrition for fast growing[5]. However, cassava foliage, fringed spiderflower *(Cleome rutidosperma)*, Asian spiderflower (*Clemone viscosa*), redflower ragleaf (*Crassocephalum crepidioides*) may be used as single feed sources. Two forms of feeding commercial concentrate feed (with >80% DM) are applied by Cambodian cricket farmers:

- feeding in wet. Farmers wet the dry feed before feeding. This increases chewability, but amounts must be calculated carefully to prevent the spoiling of leftovers
- feeding in dry. Farmers just feed the concentrate feed from the bag directly to crickets. Leftovers remain stable for a longer time, but some portions may be too hard to chew.

How often and how much feed to crickets a day?

Feed needs to be added every time the feed is gone. If the farmer is not able to determine how much to put in, a new ration should be placed when the feed is almost gone (Figures 40 to 42). Crickets eat a lot of feed during their growing phase, i.e. …

- …20 to 25 days for black crickets and
- …25 to 30 days for red crickets.

[5] Because they are in their final moult, adult crickets cannot increase in size and gain weight only moderately. However, a batch always includes some younger individuals that still can grow and gain weight in their pre-imago stages.

Figure 40: Cassava foliage, practice in large pens

Figure 41: Young cassava foliage on a tray, practice in small pens

Figure 42: Cassava foliage in large pens gone

3.2.3. Feeding pre-harvest crickets

Changing the feed of the crickets before harvest is important to ensure high-quality crickets to the consumer. Pre-harvest feed has many options depending on cricket owners and availability in the area. A selection of pre-harvest feedstuffs is presented briefly described in Tables 8 and 9 and depicted in Figures 43 to 47. However, any vegetable or fruit consumed by crickets and humans alike can be used. Change feed 24 - 48 hours before harvesting crickets has two main purposes:

- Ensure high quality and taste of the harvested crickets.
- Ensure safety, eliminating chicken and duck feed residues from the gastrointestinal tracts of the harvested animals that may cause sensorial complications for the consumer

Figure 43: Pumpkin (*Curcubita pepo*)

Figure 44: Papaya (*Carica papaya*)

Figure 45: Watermelon (*Citrullus* spp.)

Figure 46: Carrot (*Daucus carota*)

Figure 47: White leadtree leaf (*Leucaena leucocephala*)

Table 8: Typical plants used in Cambodian cricket nutrition II: pre-harvest

Family	Species	Khmer	English	Used part(s)
Apiaceae	*Daucus carota*	មើមការ៉ុត	Carrot	Root
Caricaceae	*Carica papaya*	ផ្លែល្មង	Papaya	Fruit
Curcubitaceae	*Curcubita pepo*	ផ្លែល្មៅ	Pumpkin	Fruit
	Citrullus lanatus	ផ្លែឪឡឹក	Watermelon	Fruit
Fabaceae	*Leucaena leucocephala*	ត្រួយកន្ទុំថេត	White leadtree leaf	Shoot and young leaves

Table 9: Proximate composition [%] of plants used for finishing crickets (Alabi et al., 2018; García et al., 1996; Hanif et al., 2006; Kim et al., 2012; Maisarah et al., 2014; Oladeji et al., 2016; Olayinka & Etejere, 2018; Oonicx & van der Poel, 2011)

	Moisture content	Dry matter base			
		Ash	Crude protein	Crude lipid	Crude fibre
Daucus carota	78.24 - 88.20	0.90 – 1.64	1.00 – 1.50	0.20 – 0.91	0.59 - 3.60
Carica papaya	75.35 – 92.21	5.60 – 11.41	6.08 – 33.51	0.00 ± 0.09	7.26 – 14.11
Curcubita pepo	75.63 - 84.05	4.28 – 7.43	4.25 – 12.06	1.63 – 6.07	4.32 – 14.03
Citrullus lanatus	94.06	0.34 – 0.40	0.44 – 0.80	0.00 - 0.11	0.40 - 0.43
Leucaena leucocephala	94.18	6.62 – 9.46	10.00 – 30.05	5.02	28.00 – 32.00

3.3. Water

3.3.1. Water for baby crickets

Watering the crickets after hatching should be done using a sponge or coconut rip making both materials "wet enough" and placing them onto the water tray. Small stones or rubble may also be used (Figure 48).

Figure 48: Materials used to provide water: sponge (left), coconut rip (middle), trays with rubble (right)

Figure 49: Baby crickets drink water from wet sponge

Apply water in the sponge or coconut rip (morning and evening) in two times a day (Figure 49), taking care not to leave these materials too wet (Figure 50 and 51). To ensure hygiene, it is possible to rinse sponges and coconut rip with fresh and clean water. When hygienic conditions decrease, it is important to exchange the water-supplying materials.

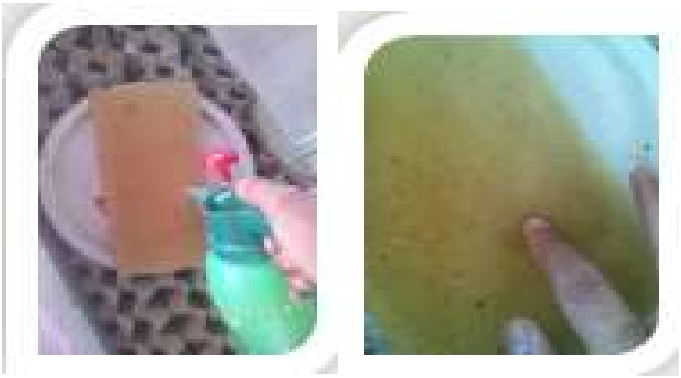

Figure 50: Provide water regularly (left) and control the degree of moisture (right)

Figure 51: Too wet sponges may pose a risk of baby crickets drowning and dying

3.3.2. Water for mature and adult crickets

Water for crickets over the age of 20 days can be supplied using a bucket cover (Figure 52) or a tray with small stones in it (Figure 53). These materials are cleaned easily, and water can be placed water directly in these trays with a depth of water less than 0.5 cm (in case of not using small stones). Water trays must be kept clean (Figure 54).

Figure 52: Bucket cover used as water tray; put water <0.5 cm on the tray (unless using small stones)

Figure 53: Adding water to the rubble-filled tray

Figure 54: Unclean (left) and clean (right) water trays

Section 4: Collection and incubation of cricket eggs

4.1. Collection of cricket eggs

Eggs are collected before the crickets are ready for sale or cooking, and when the crickets have big bellies and male crickets chirp uniformly and loudly. In order for the eggs to hatch at the same time, the eggs are collected within 24–48 hours, depending on the density of crickets. The collection of eggs for the reproductive cycle is as follows:

a) Prepare materials such as rice husk biochar (Figure 55), plastic bowls (Figure 56) and plastic bags (bags big enough for the bowls, usually bags for 3 kg).

Figure 55: Rice husk biochar

Figure 56: Plastic bowls and wet bio-char in a bucket

b) Pour the water into the container with biochar and mix to reach 80% moisture content indicated by humidity meter (Figure 57). Then, fill the bowls (3/4 of the volume) with moist biochar.
c) (Figure 58) and place inside the pens (Figure 59).

Figure 57: Moist biochar to reach approximately 80% of moisture

Figure 58: Oviposition bowls ready to use; ¾ of the bowl was filled with bio-char to avoid its spilling over into the pen

Figure 59: Oviposition bowls in the cricket pen

According to the authors' experience, the best conditions to collect cricket eggs exist when…

- …female crickets are between 30-35 (black crickets) resp. 38-45 days old (red crickets), or
- …most of the cohort displays fully developed wings, or
- …the male crickets sing uniformly and very intensively, or
- …the female crickets have bloated bellies full of eggs (Figure 60), and/or
- …very active females move around, back and forth, looking for suitable place to lay eggs.

Figure 60: Mature black cricket (*Gryllus bimaculatus*) females with bloated bellies

In order to have baby crickets of the same age, eggs should be collected at intervals of 24 to 48 hours (Figure 61).

Figure 61: Baby crickets of similar sizes hatching when eggs were collected every 24 hours

After collecting eggs for 24 hours in the same bowl, the owners need to remove the bowl with eggs from the pen, and then place it into a plastic bag for incubation (Figure 62). If farm owners need more eggs, the same procedure of eggs' collection are applied by placing in a new bowl into the pen for other 24 hours to collect cricket eggs (Figure 63).

Figure 62: Placing the bowl with cricket eggs in plastic bags for incubation

Figure 63: Place by a new bowl to collect further eggs

4.2. Incubation of cricket eggs

Check biochar regularly to see if it is (too) wet or dry. Besides using a moisture-measuring device, a practical trick is grabbing a part of the medium and press between the fingers (*cave*: use a portion with no visible eggs in it). When the hand is opened, the lump of medium should stay in the same shape, showing that moisture is the appropriate. Cricket's eggs will not hatch if the eggs in the bowls are too dry and then, water must be sprayed gently into eggs bowls to keep moisture in the bowl is around 80% (Figure 64).

Figure 64: Check the humidity content of biochar; if it is too dry, then, add water

The humidity in biochar in the egg bowl is important. If it is too dry, the eggs cannot hatch. If it is too wet, this will cause…

- …hatching rate decreases,
- …drowning crickets' babies when water droplets of water accumulate in the bags, and
- …too moist eggs can also attract so-called parasitoids, i.e. insects that lay their own eggs into the eggs' bowls. Parasitoid larvae will consume the cricket eggs, lowering the hatching rate or damage the cricket eggs in the bowl.

4.2.1. Incubation processes

Place the cricket's eggs collected (24 - 48 hours) into plastic bags and seal them well (without a large amount of air; Figure 65).

Figure 65: Preparation for cricket eggs incubation

For incubation, place the eggs in a place where they are protected from the sunlight and safe from other insects, such as predators (ants) and parasitoids (gnats and wasps; Figure 66).

Figure 66: Images of cricket eggs in sealed bowls placed suitably in the pen

After 7 to 13 days, the crickets hatch and then, the plastic bags need to be untied and opened. Bowls should be placed in a slightly tilted way (Figure 67), so that the newly hatched crickets are able to fall out of the bowl and start feeding.

Figure 67: Tilt the bowl so the baby crickets fall out of the bowl and start feeding

After the crickets hatched, water needs to be provided to them (sponge or coconut rip), soak them in enough (not too much!) water and put them in a tray for the first seven days after hatching (Figure 68). After that, the farmers can use water trays without sponge or rubble for older crickets (aged 7 to 25 days).

Figure 68: Baby crickets drink water from a sponge

Section 5: Cricket harvest

5.1 Harvesting from the containers

Grab the cardboard egg cartons with crickets a pair per time, and knock cardboard egg cartons over a larger metal or plastic container to make crickets fall into it (Figure 69).

Figure 69: Cricket harvest

Pour the crickets into another container, this time with clean water, avoiding that waste also falls into this water (Figure 70).

Figure 70: Pour the cricket into clean water

5.2. Killing and packaging harvested crickets

Killing the animals is a somewhat touchy subject, were science, culture, ethics, and practicability meet and may sometimes reach different, even opposing conclusions. This is particularly the case in insects where even their capacity of feeling pain, anxiety, and stress is debated. In terms of science, first attempts to answer these questions have been made, but their universality (be it in favour, be it against) has not been confirmed so far. Besides, the practicability also plays an important role, as especially small to medium farmers in some countries may not have the possibility to kill harvested crickets using a given technique. This, however, also applies to other livestock species, and although on the long run, this may be subjected to change, the major concern is that of people farming insects in order to improve their own nutrition and/or increase their incomes in the first place. Still, national regulation must be observed if applicable to insects.
In Cambodia, small to medium farmers have been soaking the harvested crickets in fresh water for about 1-2 hours until they are dead, as this method may be practiced without having any cooling device, as will be the case in many rural farms, especially those located in remote areas. An alternative method of killing is

using hot water (cook in boiling water for min. 10 minutes). After that, they are washed three to four times (Figure 71).

Figure 71: Crickets soak in clean water

However, recent studies have shown at least some insects experience pain and distress, and drowning or casting them into hot water are prone to create them, while cooling/freezing them or grinding them quickly are not (Baumann, 2019). In terms of animal welfare, a modified way of killing is proposed thus (Figure 72):

- Place the harvested insects in boxes, bags or nets.
- Place them into ice boxes or refrigerators to cool them down, ideally to freeze them[6]. Make sure that the bag is not too big for the cooling device so that all animals can be cooled homogenously. This can be reached by using small bags or by extending large bags so that the bag has a large surface, but a short height. When using boxes, either small one or large ones with few animals may be used.
- When crickets were actually frozen and they died, they must be washed thoroughly (three to four times, see above).
- When crickets could only be only be cooled down, then they should be placed in small batches into boiling water, so that the cooking temperatures does not drop too markedly. Make sure that the animals are actually submerged and do not remain on the surface with some parts of their bodies not surrounded by hot water. Once the water returns to boiling, keep it that way for 10 minutes to eliminate the majority of microorganisms.
- Frozen crickets are also boiled for 10 minutes, i.e. after the temperature drop and return to boiling, the process will be kept up for 10 minutes.
- Boiled crickets must be washed thoroughly in fresh and clean water, strained, drained in a clean place for one to two hours (Figure 73) and packed in clean containers (boxes or bags), labelled and stored at refrigeration temperatures.

This method is recommended for those farms that can cope with the practical requirements implied.

[6] The quickest and most effective way to freeze the animals is inside a shock froster, but this device will be an investment too high for many small-to-medium farmers. The goal, however, is to kill them by cold resp. freezing.

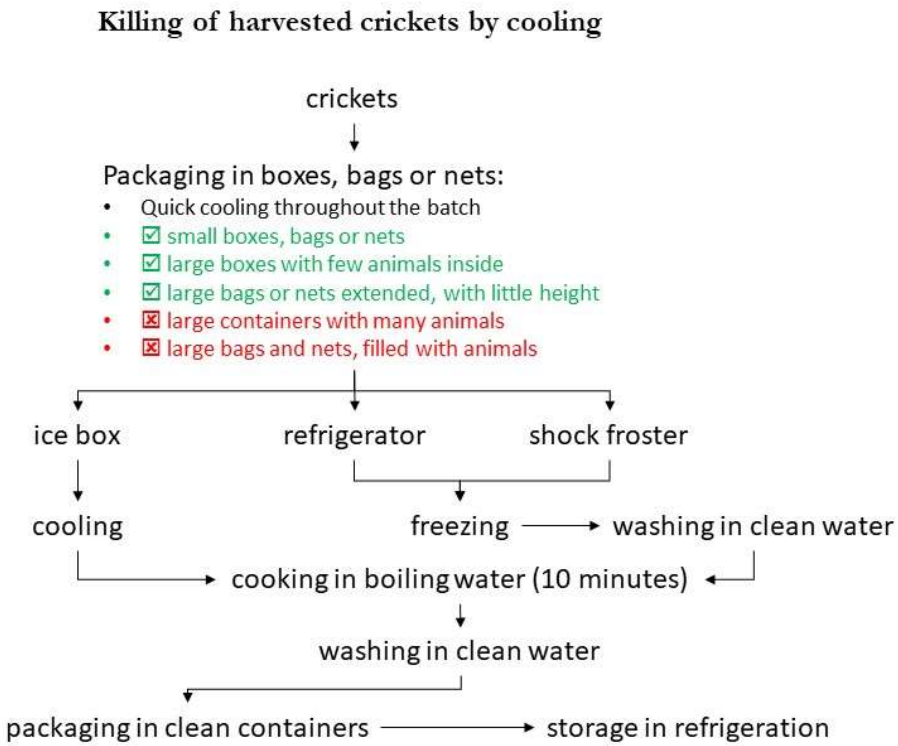

Figure 72: Killing and processing crickets according to the current state-of-the-art until storage of whole animals

Figure 73: Cricket draining in a strainer

5.3. Labelling

Labelling will depend on the planned processing of the batch and the legislation of the country the animals are farmed in. The farmers are strongly advised to consult these regulations and to observe these requirements.

- If the batch is to be processed further in the farm – i.e. the cooked and refrigerated, whole crickets will not leave the farm this way, and there is no national regulation for in-farm labelling, the farmer is free to use her or his own system. Labels should, however, include the harvesting and the best-before date. If more insect species are farmed, the name of the cricket species should also be included.
- If the batch is to be sold as such, be it to a processing plant, to a trader or to the final consumer, national labelling regulation must be consulted and headed. If no regulation exists, data on the label should, at least, contain (Figure 74):
  - Name and address of the farm (ideally, including telephone and e-mail address)
  - Name of the cricket species including the scientific name
  - Type of product ("whole, cooked")
  - Ingredients
  - Date of production (i.e. of harvesting and cooking)
  - Best-before date
  - Indication of storage (refrigerated or frozen)
  - Note on allergens[7]

An example for a fictional cricket-based product is presented in Figure X. Depending on the country and the product in question, these requirements vary. In Germany e.g., the label must also contain the ingredients with precise weights and nutritional data. The design, layout, and all other requirements are fixed in the EU regulation 1169/2011[8] and are therefore binding for all EU members.

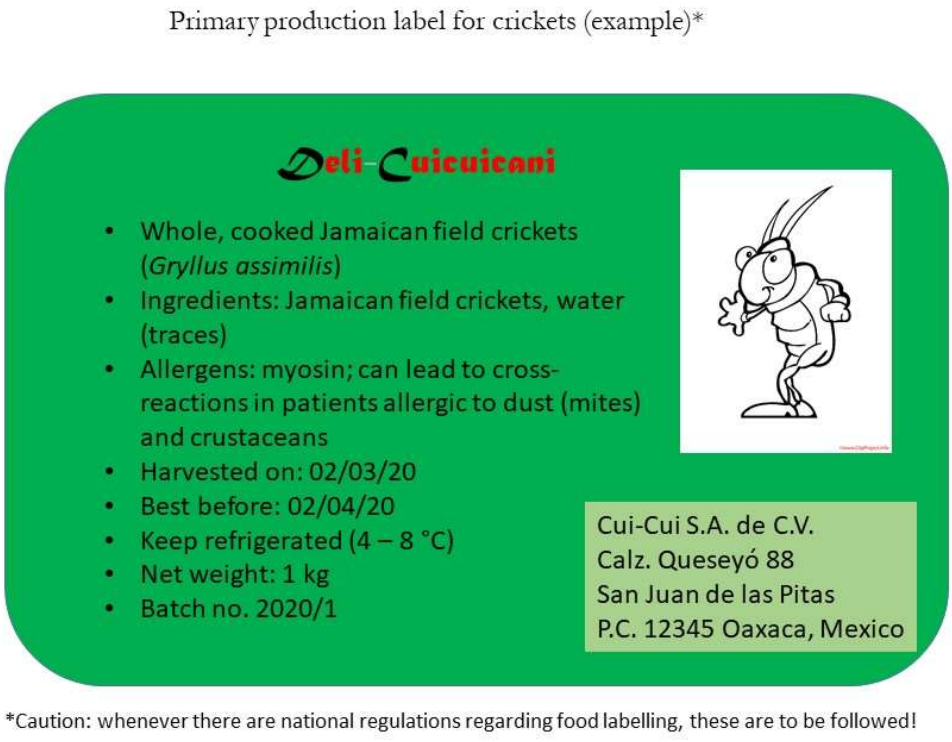

Figure 74: Labelling of a cricket-based product (minimum requirements, fictional example, especially best-before date) if there is no national labelling regulation available

[7] As with all other foodstuffs, insects contain allergens that may lead to cross-reactions in allergic patients. The most typical allergen is myosin, a protein contained in the insect muscle. In this way, patients allergic to dust, dust mites, and/or crustaceans may experience cross-reactions when consuming insects.

[8] Consolidated version: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:02011R1169-20180101&from=EN

5.4. Storage

Store in freezer for sale or home consumption (Figure 75 and 76). Insects spoil easily, especially at warm temperatures. Cooking extends shelf life, but insects need to be kept in refrigeration. After cleaning, cooking and packaging, heated crickets can be stored in…

- …an ice box: two to three days
- …a refrigerator: one to three months (at 8 – 10 °C)
- …a freezer: one year (at -20 to -18 °C).

Figure 75: Cricket packing (2kg/set) in plastic bag and storage in refrigerator

Figure 76: Tasting of prepared crickets: crickets were harvested from one of the farms (rearing farm) in Pursat (Western Cambodian province), funded by the Ørskov Foundation and implemented by the Association Saving Poor Family for Development (ASPFD) as a partner of LDC (formerly CelAgrid). Farmers prefer to fry the crickets in vegetable oil, mixing them with ingredients such as duck eggs, salt, sugar, chili, lemongrass, monosodium glutamate, and kaffir lime leaves before deep-frying them.

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