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# A Review on Insect Farming in China

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**Abstract:** *Insect farming has gained increasing attention in China as a sustainable solution to growing food security challenges, organic waste management, and environmental degradation. This review synthesizes research published prior to 2019 to explore the development, species diversity, technological progress, environmental benefits, economic viability, and policy limitations of insect farming in China. Major insect species such as Tenebrio molitor, Hermetia illucens, Zophobas morio, and Bombyx mori are assessed in terms of their nutritional profiles, feed conversion efficiency, and applicability in food and feed systems. Pre-2019 literature also highlights significant advances in bioengineering, environmental control systems, and integration of insect-based organic fertilizers into circular agriculture. Despite these achievements, fragmented regulatory frameworks and limited consumer acceptance posed significant challenges to industry scaling. Nonetheless, early adoption of IoT and genomic tools indicated that China was preparing to emerge as a global leader in insect biotechnology. This review offers a baseline for understanding the evolution and future trajectory of insect farming in China at the close of the 2010s.*

**Keywords:** Insect farming · China · Sustainable agriculture · Black soldier fly

## I. INTRODUCTION

The practice of using insects as a source of food and feed in China dates back thousands of years, with entomophagy (the consumption of insects) being deeply embedded in many regional culinary traditions. Edible insects such as silkworm pupae, cicadas, grasshoppers, and locusts have long been considered not only a delicacy but also a source of medicinal and nutritional value in Chinese traditional knowledge systems. Insects are praised for their high protein content, low environmental footprint, and efficiency in converting organic matter into biomass—qualities that make them attractive in the face of rising global food security concerns.

In recent decades, the role of insects in China has transitioned from traditional consumption to becoming an integral part of agricultural innovation and biotechnology. The growth of China's insect farming industry reflects broader trends in sustainable agriculture, waste management, and circular economy strategies. Notably, China has emerged as one of the foremost developers of insect-based technologies, particularly for converting food waste into animal feed using species such as *Hermetia illucens* (black soldier fly) and *Tenebrio molitor* (mealworms).

By 2019, China had firmly positioned itself as a global leader in insect utilization, not only in terms of consumption volumes but also in research outputs and commercial applications. Chinese universities and research institutions were conducting studies on insect genetics, nutritional profiling, environmental impacts, and automation in farming systems. Enterprises were experimenting with large-scale insect rearing facilities, integrating advanced technologies like climate control, artificial intelligence, and robotic feeding systems.

Furthermore, government policy in 2019 began to acknowledge the potential of insect farming as part of sustainable agriculture and rural revitalization. Though still in its early phases of regulation, there were initial discussions on standardizing practices and enhancing food safety mechanisms to support the commercialization of insects for both human and animal consumption.

This multifaceted evolution—from ancient practice to modern industry—has placed China at the forefront of global efforts to develop insects as a reliable and ecologically sound resource. As the international demand for sustainable protein sources continues to grow, China's experience and infrastructure provide a valuable model for the integration of tradition and innovation in the food system.

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## II. SPECIES DOMESTICATED AND COMMERCIALIZED

China's insect farming landscape is underpinned by both traditional entomophagy practices and emerging commercial models. Prior to 2019, significant progress had already been made in the domestication and commercialization of several key insect species, which served as the foundation for the rapid growth observed in more recent years.

### 2.1 Tenebrio molitor (Mealworms)

Mealworms have long been studied in China for their protein content and use as feed. Their ability to convert low-value organic materials into high-protein biomass was well-documented. Early evaluations highlighted their suitability for mass rearing in controlled environments using crop residues (Feng et al., 2017). With protein content averaging 50% of dry mass and a favorable amino acid profile, Tenebrio molitor became widely used in both aquaculture and poultry feed trials (Zhang et al., 2016).

### 2.2 Hermetia illucens (Black Soldier Fly)

Before 2019, Hermetia illucens had already become a focus of ecological engineering in China, particularly for organic waste bioconversion. Researchers such as Liu et al. (2017) demonstrated that BSF larvae could efficiently degrade food and livestock waste, yielding both insect biomass and nutrient-rich frass usable as fertilizer. Pilot projects launched in southern China, especially in Guangdong, showed that BSF larvae could reduce waste volumes by over 60% within 10 days while producing high-protein larvae for feed.

### 2.3 Zophobas morio (Superworms)

While less widely researched than mealworms or BSF, Zophobas morio was known in the entomological and exotic pet industries. Trials conducted by Wu and colleagues (2015) found that Zophobas had a faster growth rate and higher lipid content than Tenebrio, making them useful for high-fat feed formulations. However, their cannibalistic behavior and greater sensitivity to humidity fluctuations made them less ideal for large-scale farming at the time.

### 2.4 Bombyx mori (Silkworm)

The silkworm *Bombyx mori* has been domesticated in China for over two millennia, primarily for silk production. However, by the 2010s, silkworm pupae—previously discarded or used locally—were increasingly being evaluated for their potential as a high-protein feed and human food supplement. A study by Chen et al. (2015) confirmed that defatted silkworm pupae contained approximately 60% crude protein and were well tolerated in poultry diets. Furthermore, Ma et al. (2016) addressed safety concerns, noting the need for allergen management in human applications.

### 2.5 Other Edible and Pilot Species

Beyond the primary commercial species, China has explored rearing of other insects such as *Acheta domesticus* (house crickets) and *Locusta migratoria* (migratory locust). Though mostly gathered wild or semi-cultivated for traditional medicine and gourmet dishes, studies like that of Wang and Yao (2014) suggested strong market potential due to increasing consumer interest in novelty foods and the low environmental impact of rearing insects compared to livestock.

Table No. 1 Nutritional composition and farming applications of common insect species farmed in China

| Insect Species | Protein (%) | Fat (%) | Fiber (%) | Main Use | Feed Conversion Ratio (FCR) |
|---|---|---|---|---|---|
| *Tenebrio molitor* (Mealworm) | 47 | 30 | 6 | Feed & Food | 2.2 |
| *Hermetia illucens* (Black Soldier Fly) | 42 | 35 | 15 | Waste Conversion & Feed | 1.8 |
| *Zophobas morio* (Superworm) | 45 | 38 | 10 | Pet Feed & Poultry | 2.5 |
| *Bombyx mori* (Silkworm Pupae) | 55 | 27 | 6 | Byproduct from Silk Industry | 2 |

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| | | | | | |
|---|---|---|---|---|---|
| *Acheta domesticus* (House Cricket) | 65 | 20 | 10 | Specialty Food & Feed | 1.7 |

Data compiled from *Feng et al. (2017)*, *Liu et al. (2017)*, *Zhou & Han (2016)*, *Yi et al. (2013)*, and *FAO (2013)*

## III. TECHNOLOGICAL ADVANCES IN INSECT FARMING

Before the explosive development of AI-powered automation seen after 2019, China had already made meaningful strides in deploying technology to enhance insect farming. These innovations primarily focused on improving rearing systems, monitoring efficiency, environmental control, and waste-to-protein bioconversion through mechanization and information systems.

### 3.1 Automation and Environmental Control

Early insect farming systems in China relied on labor-intensive methods. However, researchers began introducing automated systems by the mid-2010s to enhance productivity. According to Zhang et al. (2016), temperature and humidity control systems were implemented in Tenebrio molitor (mealworm) production facilities to improve consistency in larval growth and reduce mortality. These systems employed programmable logic controllers (PLCs) and basic sensors to regulate climate conditions based on insect developmental stages.

### 3.2 Bio-Waste Conversion Technologies

Significant innovation occurred in black soldier fly (*Hermetia illucens*) farming for organic waste management. Liu et al. (2017) conducted trials showing that automated larval feeding systems using conveyor belts and batch feeders dramatically reduced manual labor and increased throughput in BSF rearing units. They emphasized the importance of waste pre-processing machines, such as grinders and fermenters, to improve the digestibility of food waste for larvae.

### 3.3 Image-Based Monitoring and Detection

While deep learning applications in agriculture were still emerging, He et al. (2015) experimented with early image recognition systems to monitor pest density in silkworm farms. These systems, though rudimentary, paved the way for precision monitoring in closed insect rearing environments. Multispectral sensors and low-resolution infrared imaging were used to detect abnormal movements or mortality spikes among silkworm larvae.

### 3.4 Integration of IoT and Data Logging

By 2018, certain pilot farms began incorporating IoT (Internet of Things) platforms to track insect farming data in real-time. Feng et al. (2018) reported the development of a centralized monitoring dashboard for BSF and mealworm facilities in Sichuan province. The system included RFID-tagged trays for insect batches, allowing automated weight measurements, environmental readings, and production rate logging—all accessible via mobile apps.

### 3.5 Technological Training and Dissemination

The Chinese Ministry of Agriculture and various agricultural universities played a key role in disseminating these technologies. Zhou & Yang (2014) emphasized the role of "smart agriculture" pilot centers in training rural farmers to adopt mechanized insect farming tools. These efforts were especially focused on bridging the technology gap in underdeveloped regions.

## IV. ENVIRONMENTAL AND NUTRITIONAL BENEFITS (PRE-2019 LITERATURE)

Insect farming is widely recognized for its significant environmental advantages and superior nutritional profile, especially when compared to conventional livestock production. These benefits have been increasingly explored in Chinese agricultural research as the country seeks to improve food security while reducing ecological degradation.

### 4.1 Environmental Sustainability

Insects require far less land, water, and feed than traditional livestock, and emit significantly lower levels of greenhouse gases. For example, Oonincx et al. (2012) quantified that the greenhouse gas emissions of mealworms are substantially lower than those of pigs or cattle per unit of protein produced. In the context of China, this offers a promising pathway for sustainable protein production in densely populated and resource-constrained regions.

The black soldier fly (*Hermetia illucens*) has become particularly important in China for its waste-reducing potential. Liu et al. (2017) demonstrated that BSF larvae could convert organic kitchen and agricultural waste into high-protein biomass, while the residue (frass) could be applied as an organic fertilizer. This process not only recycles nutrients but also reduces methane emissions from landfill waste decomposition.

Moreover, insect farming presents an opportunity to reduce the ecological footprint of aquaculture and livestock feed. According to van Huis et al. (2013), insects can be reared on organic side streams and thus help close nutrient loops within agroecosystems—a key objective for China's sustainable agriculture strategies.

### 4.2 Nutritional Efficiency

Insects are naturally rich in protein, essential amino acids, fatty acids, vitamins (particularly B12), and minerals such as iron and zinc. Feng et al. (2017) evaluated the composition of *Tenebrio molitor* and found protein content ranging from 47%–58% (dry weight), along with favorable lipid profiles rich in unsaturated fatty acids. Such nutritional densities make insects a valuable supplement or alternative to fishmeal and soy-based feeds.

In particular, Zhou & Han (2016) highlighted that the amino acid profile of silkworm pupae is comparable to that of high-quality fishmeal, and its digestibility in poultry and pig diets is high. Furthermore, due to the presence of bioactive compounds like chitin and antimicrobial peptides, insects may offer additional health benefits when used in animal feed—such as improved gut microbiota and immune response (Yi et al., 2013).

### 4.3 Ecological Integration

Beyond direct nutritional and emissions metrics, insect farming supports a broader ecological approach. Zhang et al. (2015) investigated integrated farming systems in rural China where insect rearing (such as silkworms and BSF) was combined with organic crop production. These systems demonstrated reduced chemical input dependency and improved soil organic matter when insect frass was applied as compost.

## V. ECONOMIC VIABILITY

The economic potential of insect farming in China has garnered increasing attention as both rural communities and agribusiness sectors search for cost-effective and sustainable alternatives to traditional protein sources. Several studies conducted before 2019 confirmed that insect farming can offer lower input costs, higher biomass yield per unit area, and greater compatibility with circular agricultural practices compared to conventional livestock systems.

### 5.1 Cost-Effectiveness and Resource Use

Insect farming requires significantly fewer resources—such as land, water, and feed—than traditional animal farming. Feng et al. (2017) reported that Tenebrio molitor could be reared on by-products like wheat bran and spent grains with a feed conversion ratio (FCR) nearly three times more efficient than poultry. These efficiencies translate directly into economic advantages, especially for smallholder farmers with limited capital.

### 5.2 Rural Development and Circular Economy Models

Research by Zhang & Zhao (2016) demonstrated that integrating insect farming into rural production systems—particularly in Yunnan, Sichuan, and Guizhou provinces—enhanced the productivity and income stability of smallholder farmers. The insects, especially black soldier fly and mealworms, were used to convert organic waste into feed, reducing the cost of commercial feed inputs by up to 40%. The frass (insect manure) was then used as fertilizer, supporting vegetable and tea cultivation in mountain regions.

These circular practices not only enhanced self-sufficiency but also offered added income through local and regional markets. In cases studied by Liu et al. (2015), silkworm pupae were sold in local markets as both food and feed, providing an additional income stream to traditional silk producers.

5.3 Competitive Advantage Over Poultry and Aquaculture

The comparative analysis conducted by Han et al. (2014) indicated that insect farming yielded a 20–30% higher return on investment than broiler chicken farming when infrastructure costs were normalized. Insects like *Zophobas morio* and *Tenebrio molitor* also had shorter life cycles and required less labor, making them ideal for urban and peri-urban farming systems.

5.4 Barriers and Scaling Limitations

Despite these advantages, pre-2019 studies also emphasized the economic challenges of scaling insect farming. Wu & Chen (2013) noted that the lack of formal market structures and regulatory standards for insect-derived feed limited mass adoption. Moreover, insect protein prices were still high relative to soybean meal due to the novelty of processing technologies.

However, several provincial governments began offering subsidies and technical training to farmers interested in integrating insect farming, as documented in reports by Yang & Mei (2016). These initiatives aimed to encourage rural entrepreneurship, reduce organic waste accumulation, and support green agriculture.

## VI. APPLICATIONS IN ANIMAL FEED AND ORGANIC FERTILIZER (PRE-2019 LITERATURE)

Insects have proven to be a dual-function resource in agricultural systems—serving not only as a high-protein ingredient in animal feed but also as a vector for transforming organic waste into nutrient-rich fertilizer. These applications are of particular interest in China, where large volumes of agricultural residues and livestock waste pose environmental challenges and where demand for sustainable feed solutions is growing rapidly.

### 6.1 Insects as Animal Feed

The use of insects in feed formulation is well-established in China, especially for poultry, aquaculture, and swine production. Prior to 2019, a number of feeding trials confirmed the nutritional adequacy and economic feasibility of using insects like *Tenebrio molitor*, *Zophobas morio*, and *Hermetia illucens*.

Zhou and Han (2016) demonstrated that silkworm pupae meal could replace up to 50% of fishmeal in broiler diets without compromising growth performance or carcass quality. This was particularly relevant for inland provinces with access to silkworm rearing operations. Similarly, Feng et al. (2017) evaluated *Tenebrio molitor* meal as an aquafeed protein source, finding it to be highly digestible and cost-effective when larvae were reared on agro-industrial by-products.

Additionally, Liu et al. (2015) studied the inclusion of black soldier fly larvae in piglet diets, reporting enhanced feed conversion ratios and reduced gut pathogens due to the larvae's antimicrobial peptide content.

### 6.2 Insect Frass as Organic Fertilizer

The by-products of insect farming, particularly frass (excrement and shed exoskeletons), are rich in nitrogen, phosphorus, and potassium, and serve as excellent biofertilizers. In trials conducted by Zhang et al. (2015), frass from BSF larvae reared on food waste improved the organic matter content and microbial activity in paddy soils, enhancing rice yields by up to 15% compared to conventional compost.

Chen and Zhao (2016) noted that the microbial diversity in frass helps suppress soil-borne pathogens and promotes beneficial fungi such as *Trichoderma* and *Bacillus* species, providing both nutritional and phytoprotective effects.

These benefits support China's national goals for reducing dependence on chemical fertilizers and promoting ecological agriculture. In particular, integrated systems that combine BSF-based waste treatment with organic fertilizer recovery were piloted in peri-urban areas of Guangzhou and Chengdu before 2019.

### 6.3 Circular Agriculture and Policy Relevance

The combination of insect-based feed and fertilizer systems fits well into the Chinese policy framework for circular agriculture. According to Yang and Mei (2016), regional governments began promoting pilot programs where insects processed kitchen waste and livestock manure into both feed and fertilizer, thereby closing nutrient loops and minimizing pollution.

This integrated model reduces input costs, adds value to waste, and provides an avenue for rural livelihoods through decentralized, small-scale insect farms.

## VII. CHALLENGES AND REGULATORY GAPS (PRE-2019 LITERATURE)

Despite the clear environmental, economic, and nutritional benefits of insect farming in China, the industry has long been held back by fragmented regulations, limited standardization, and consumer skepticism. These issues were widely documented in academic and policy literature prior to 2019, highlighting key structural and institutional barriers to sectoral growth.

### 7.1 Absence of Unified Regulatory Framework

One of the main obstacles identified was the lack of a coherent national regulatory framework governing insect-based food and feed. Wu and Chen (2013) reported that as of 2013, regulatory responsibilities were split among different departments such as the Ministry of Agriculture, the State Food and Drug Administration (SFDA), and provincial environmental bureaus. This jurisdictional fragmentation resulted in uncertainty for startups and limited investment in scale-up operations.

Furthermore, Yang and Mei (2016) noted that many insect farming enterprises operated under local licenses intended for aquaculture or composting rather than food-grade or feed-grade manufacturing. This regulatory mismatch exposed producers to enforcement risks and made it difficult to access financial credit or insurance.

### 7.2 Food Safety and Market Trust

Food safety remained a significant concern, especially for insects intended for direct human consumption. Prior to 2019, no clear national food safety standards existed for insects, apart from legacy policies that governed silkworm pupae in traditional food contexts. Chen and Zhao (2016) emphasized the need for microbial hazard controls and allergen testing protocols, particularly for insects like BSF and crickets, which had limited human consumption histories in China.

Consumer attitudes also presented a challenge. According to Zhang and Wang (2015), public surveys in Beijing and Shanghai indicated low willingness to adopt insect-based foods, particularly among urban populations with higher purchasing power. Negative perceptions related to hygiene and safety were more significant than concerns about taste or nutrition.

### 7.3 Technical Training and Knowledge Gaps

Another regulatory gap was the absence of formal technical certification programs or curriculum-based training for insect farming. Most knowledge dissemination occurred via regional agricultural extension centers or private consultants. Liu et al. (2015) criticized this model as insufficient for modern production standards, especially given the biological complexities of mass-rearing insects under controlled conditions.

### 7.4 Import/Export Restrictions

Pre-2019 literature also highlighted constraints on international trade involving insect-derived products. For example, Feng et al. (2017) pointed out that although mealworm protein and BSF oil were accepted in the EU and parts of Southeast Asia, China's classification of insect products as “novel foods” often resulted in export restrictions due to lack of harmonized safety evaluations and documentation.

## VIII. FUTURE PROSPECTS (PRE-2019 LITERATURE)

China is poised to remain a global leader in insect farming and biotechnology, driven by a combination of agricultural innovation, government interest, and environmental necessity. Although much of the AI- and IoT-enhanced insect farming boom has accelerated post-2019, several studies and policy discussions prior to that year already laid the foundation for future developments.

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8.1 Integration of Smart Farming Technologies

While most large-scale applications of AI and machine learning (ML) in insect farming have only gained prominence in the 2020s, the conceptual and technical groundwork was already evident before 2019. As early as 2016, Feng et al. (2017) emphasized the use of digital sensors and semi-automated monitoring systems in *Tenebrio molitor* farms in Sichuan. These early efforts involved environmental sensors connected to basic control units for managing temperature and humidity—critical for insect rearing efficiency.

In parallel, the National Agricultural Internet of Things Laboratory released frameworks between 2016–2018 to promote IoT-based monitoring systems in greenhouse and insect farming operations, foreshadowing more advanced smart farming applications (Zhang & Li, 2018).

8.2 Biotechnology and Genomic Research

Research in insect genomics, particularly on the black soldier fly and silkworm, advanced considerably in China before 2019. Wu et al. (2017) described silkworm gene-editing platforms using CRISPR-Cas9 to optimize silk and pupae output, while Chen and Zhao (2016) identified insect strains better suited for mass rearing through selective breeding.

These biotechnology applications are crucial for improving yield, disease resistance, and nutritional quality of insect products—making them commercially viable for both domestic and export markets.

8.3 Policy Support and International Alignment

Even before the official inclusion of insects in national agricultural planning, several pilot provinces—such as Guangdong, Yunnan, and Sichuan—had launched regional programs promoting insect protein as a sustainable food and feed source. According to Yang and Mei (2016), these programs focused on integrating insects into local circular economy models, providing subsidies, technical training, and access to microfinancing.

Moreover, Chinese researchers participated in international panels coordinated by the FAO and OECD, contributing to global discussions on edible insects and pushing for standardized regulations and cross-border trade frameworks (FAO, 2013).

8.4 Forecast and Outlook

Based on these developments, China's future in insect farming appears strongly linked to:

i. Integration of AI and IoT for scalable and automated production.
ii. Investment in bioengineering to enhance insect productivity and resilience.
iii. Policy standardization for national food/feed safety and international market access.
iv. Urban vertical farming models that incorporate insects as part of food–waste–energy loops.

With a rising domestic demand for sustainable proteins and increasing global interest in environmentally friendly food systems, China is well-positioned to lead the transition toward high-tech insect bioconversion models.

## IX. CONCLUSION

As of 2019, insect farming in China stood at a critical juncture—anchored in millennia-old traditions but rapidly evolving into a scientifically supported and economically promising industry. China's leadership in insect biotechnology was evident through its pioneering research on species such as *Tenebrio molitor*, *Hermetia illucens*, *Zophobas morio*, and *Bombyx mori*, each offering distinct advantages in food security, animal nutrition, and environmental sustainability.

Pre-2019 research highlighted insects' superior feed conversion efficiency, lower greenhouse gas emissions, and ability to transform organic waste into valuable biomass and fertilizer. These traits made insects a natural fit for China's circular economy models, particularly in rural areas where decentralized, low-input systems can be scaled effectively. Moreover, the nutritional profile of edible insects positions them as an alternative to traditional protein sources in both animal feed and, increasingly, human diets.

Despite these strengths, several regulatory and infrastructural gaps persisted. A fragmented policy environment, absence of standardized safety guidelines, and limited consumer acceptance impeded widespread commercialization.

However, growing investment in biotechnological tools, early-stage automation, and IoT-based environmental control systems indicated China's intent to modernize the sector.

Looking ahead from the vantage point of 2019, the integration of artificial intelligence, machine learning, and bioengineering in insect farming appeared not only feasible but inevitable. With strategic policy support and continued research, China was on track to not only meet its domestic sustainability goals but also to shape global discourse on next-generation protein and agroecological systems.

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