UNIVERSIDADE PAULISTA

JAQUELINE GEISA CUNHA GOMES

CADEIA DE VALOR DOS INSETOS COMESTÍVEIS NO BRASIL:
Ecoinovação para o futuro da proteína

SÃO PAULO

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Tese apresentada ao Programa de Pós-Graduação em Engenharia de Produção da Universidade Paulista – UNIP, para a obtenção do título de Doutora em Engenharia de Produção.

Área de concentração: Gestão de sistemas de operação.

Linha de pesquisa: Redes de empresas e planejamento da produção

Projeto de pesquisa: Gestão da Produção e Inovação na Agricultura, Indústria e Serviços

Orientador: Prof. Dr. Marcelo Tsuguio Okano.

SÃO PAULO

2025

Gomes, Jaqueline Geisa Cunha.
Cadeia de valor dos insetos comestíveis no Brasil: ecoinovação para o futuro da proteína / Jaqueline Geisa Cunha Gomes. – 2025.
146 f. : il. color. + CD-ROM.

Tese de Doutorado Apresentada ao Programa de Pós-Graduação em Engenharia de Produção da Universidade Paulista, São Paulo, 2025.
Área de concentração: Gestão de Sistemas de Operação.
Orientador: Prof. Dr. Marcelo Tsuguio Okano

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1. Proteína alternativa. 2. Insetos comestíveis. 3. Cadeia de valor. 4. Ecoinovação. 5. Indicadores de desempenho. I. Okano, Marcelo Tsuguio (orientador). II. Título.

Ficha elaborada pelo Bibliotecário Rodney Eloy CRB8-6450

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À minha filha Marol,

que, enquanto eu a gestava, também plantou em mim as primeiras ideias deste caminho. Desde então, mãe, filha e pesquisa caminham juntas. Que você cresça sabendo que muito é possível quando se unem amor, propósito e vontade.

AGRADECIMENTOS

Ao meu pai, Valdomiro de quem herdei o fascínio pelo conhecimento sem fim, seu exemplo me ensinou que a busca pelo saber é uma forma de liberdade.

Ao meu marido e amigo, Bruno, por reconhecer e apoiar a busca incessante pelo meu desejo de aprender, sua generosidade, ao me permitir investir tempo, energia e coração nesta tese, foi essencial para que ela acontecesse.

À minha filha Marol, por ter aceitado outros colos enquanto eu me dedicava a esta pesquisa, sua existência me dá sentido, força e a inspiração constante para acreditar em um futuro melhor.

Ao meu orientador, Okano que acreditou no meu potencial desde o início do mestrado e, desde então, apoiou a construção desta tese, cuja indústria ainda é desconhecida por muitos, mas que ele acolheu com abertura e confiança.

À minha amiga e colega de jornada desde o mestrado, Samira, com quem compartilho as alegrias e os desafios da vida acadêmica, sua persistência me inspirou a seguir em frente.

Às biofábricas que abraçaram meu sonho e abriram suas portas a uma desconhecida, cheia de perguntas e vontade de aprender.

À ASBRACIA, que me recebeu com gentileza e viabilizou a coleta de dados fundamental para a aplicabilidade desta tese.

À Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) - Brasil, pelo apoio institucional e financiamento concedido.

Aos que caminham comigo com verdade no coração, meu agradecimento silencioso e eterno.

“Eu estava cercado por uma vida construída para mim, e não por mim. Mas nem nos meus sonhos mais loucos eu poderia imaginar aonde isso iria me levar”.

Michael A. Singer

RESUMO

As projeções da Food and Agriculture Organization of the United Nations (FAO) indicam que a produção global de proteínas precisará crescer mais de 60% até 2050 para alimentar uma população estimada em 9 bilhões de pessoas. Nesse cenário, a cadeia de valor dos insetos comestíveis desponta como uma alternativa promissora, integrando soluções sustentáveis para a produção de proteína, com menor uso de terra, água e emissões de gases de efeito estufa. Esta tese tem como objetivo geral analisar a cadeia de valor dos insetos comestíveis no Brasil, investigando seu alinhamento com os princípios de sustentabilidade e ecoinovação por meio do desenvolvimento e da avaliação de indicadores de desempenho. No Brasil, a cadeia encontra-se em processo de estruturação, impulsionada por iniciativas empresariais de pequeno porte, principalmente por microempreendedores individuais e microempresas. A produção concentra-se em espécies como *Hermetia illucens* e *Tenebrio molitor*, com foco em rações para animais de estimação, peixes e suínos, além de segmentos como fertilizantes. Os produtos são comercializados na forma viva, processada ou desidratada. Apesar de o consumo de insetos não ser proibido pela lei brasileira, a falta de regulamentação específica impossibilita a obtenção de licenças para empresas. Consequentemente, muitas operam de maneira informal ou restringem suas atividades a projetos de pesquisa. A metodologia da pesquisa combinou análise bibliométrica, revisão sistemática, estudo de caso múltiplo com uso de SWOT e Canvas, e análise estatística por correlação de Spearman e Análise Fatorial Exploratória – AFE. Como principais achados, a análise dos casos brasileiros revelou gargalos estruturais relacionados ao baixo nível de financiamento, deficiência tecnológica, falta de mão de obra qualificada e desorganização na estrutura de fornecedores. Complementarmente, a análise estatística destacou cinco indicadores com alta centralidade e relevância para o desempenho da cadeia: qualidade das relações com fornecedores, segmentação de mercado, previsão de preços, vantagem competitiva e eficiência na conversão de insumos em produtos finais. Esses fatores apontam a necessidade de maior integração dos elos produtivos e fortalecimento institucional da cadeia.

Palavras-chave: proteína alternativa, insetos comestíveis, cadeia de valor, ecoinovação, indicadores de desempenho.

ABSTRACT

Food and Agriculture Organization of the United Nations (FAO) projections indicate that global protein production will need to increase by more than 60% by 2050 to feed an estimated population of 9 billion people. In this context, the value chain of edible insects emerges as a promising alternative, offering sustainable solutions for protein production with lower land use, water consumption, and greenhouse gas emissions. This thesis aims to analyze the value chain of edible insects in Brazil, investigating its alignment with the principles of sustainability and eco-innovation through the development and evaluation of performance indicators. Brazil's chain is still structured and driven by small-scale entrepreneurial initiatives, particularly individual micro-entrepreneurs, and micro-enterprises. Production is concentrated in species such as *Hermetia illucens* and *Tenebrio molitor*, primarily targeting pet food, fish feed, pig feed, and fertilizer segments. The products are sold in live, processed, or dehydrated forms. Although the consumption of insects is not prohibited by Brazilian law, the absence of specific regulations prevents companies from obtaining the necessary licenses. As a result, many operate informally or limit their activities to research projects. The research methodology combined bibliometric analysis, systematic review, multiple case studies using SWOT and the Sustainable Business Model Canvas, and statistical analysis through Spearman's correlation and Exploratory Factor Analysis (EFA). The main findings indicate structural bottlenecks in the Brazilian cases, including low levels of financing, technological deficiencies, lack of qualified labor, and disorganized supplier structures. Additionally, the statistical analysis highlighted five indicators with high centrality and strategic relevance for the value chain's performance: quality of supplier relationships, market segmentation, price forecasting, competitive advantage, and efficiency in converting inputs into final products. These factors point to the need for greater integration among production chain links and institutional strengthening of the sector.

keywords: alternative protein, edible insects, value chain, eco-innovation, performance indicators.

UTILIDADE - VALOR SOCIAL, ECONÔMICO E AMBIENTAL DA TESE

A cadeia de valor dos insetos comestíveis apresenta potencial para promover segurança alimentar e reduzir a pobreza por meio da geração de renda local, fortalecer práticas produtivas inovadoras baseadas na ecoinovação, ampliar a adoção de modelos de negócio sustentáveis com aproveitamento de resíduos e oferecer subsídios gerenciais para que empreendedores possam identificar gargalos, priorizar investimentos e acompanhar a evolução dos processos produtivos. Essas contribuições estão alinhadas a objetivos globais como Erradicação da Pobreza (ODS 1), Fome Zero e Agricultura Sustentável (ODS 2), Trabalho Decente e Crescimento Econômico (ODS 8), Indústria, Inovação e Infraestrutura (ODS 9), Consumo e Produção Responsáveis (ODS 12), Ação Contra a Mudança Global do Clima (ODS 13), Vida na Água (ODS 14) e Vida Terrestre (ODS 15).

Ao mapear e analisar criticamente os fatores que impactam a eficiência produtiva, a competitividade e o uso de recursos naturais na cadeia de insetos comestíveis, esta tese contribui com diretrizes práticas para o desenvolvimento de modelos mais sustentáveis e inclusivos, promovendo avanços concretos em direção aos Objetivos de Desenvolvimento Sustentável estabelecidos pela Agenda 2030.

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ASBRACIA – Associação Brasileira dos Criadores de Insetos Alimentícios

FAO – Food and Agriculture Organization of the United Nations

IPIFF – International Platform of Insects for Food and Feed

KPI – Key Performance Indicators

ODS – Objetivos de Desenvolvimento Sustentável

ONU – Organização das Nações Unidas

PAPs – Proteínas Animais Processadas

SWOT – Strengths, Weaknesses, Opportunities, Threats

UE – União Européria

SUMÁRIO

1 INTRODUÇÃO

A crescente demanda global por proteínas, impulsionada pelo aumento populacional, exigirá um aumento de 60% na produção até 2050 para alimentar uma população mundial de aproximadamente 9 bilhões de pessoas (ONU, 2015). Nesse contexto, a produção de insetos comestíveis surge como uma alternativa sustentável tanto para o consumo humano quanto para ração animal (Van Huis, 2015).

Embora a entomofagia (consumo de insetos como fonte alimentar) tenha declinado com o desenvolvimento das sociedades modernas, ela ainda é praticada em 113 países, com 2.111 espécies de insetos consumidas por cerca de 2 bilhões de pessoas, principalmente em regiões tropicais (FAO, 2013). No Brasil, essa prática é observada em 14 estados, especialmente entre 39 tribos indígenas (Costa-Neto, 2016). Estudos mostram que os insetos oferecem nutrientes essenciais, como lipídios e vitaminas, além de serem uma alternativa econômica em relação às proteínas animais convencionais (Patel *et al.*, 2019; Li *et al.*, 2023).

Diante desse contexto, a cadeia de valor dos insetos comestíveis tem o potencial de se consolidar como um sistema alimentar sustentável, pois pode garantir a segurança alimentar por meio de nutrientes, além de manter os pilares financeiro, social e ecológico da sustentabilidade em longo prazo (Kawabata *et al.*, 2020). Além disso, já existem evidências sobre o impacto das mudanças climáticas e do crescimento populacional nas populações de insetos selvagens (Musundire *et al.*, 2021).

Nesse contexto, a cadeia de valor pode ser entendida a partir da estrutura proposta por Kaplinsky e Morris (2001), que permite identificar onde o valor é gerado e onde os gargalos dificultam o progresso. Bermúdez-Serrano (2020) destaca que a configuração da cadeia de valor de insetos comestíveis varia de acordo com o contexto local, em algumas regiões, segue tradições consolidadas; em outras, ainda está se formando. De forma geral, porém, quatro estágios principais tendem a se repetir: (1) fornecimento de insumos: como subprodutos orgânicos e ingredientes especializados para alimentação; (2) produção de insetos: desde a coleta em ambiente natural até criações familiares ou biofábricas em escala industrial; (3) processamento: em que os insetos são transformados em ingredientes intermediários ou produtos acabados para os mercados alimentício, de ração, farmacêutico e cosmético; e (4) distribuição e consumo: abrangendo canais como feiras, supermercados, restaurantes e comércio eletrônico. Mapear esses estágios e suas interações permite racionalizar operações, reduzir custos e elevar a qualidade dos produtos. Essa visão sistêmica também estimula a especialização dos produtores e a adoção de inovações tecnológicas, elementos essenciais para construir uma cadeia de valor eficiente, sustentável e competitiva em escala global (Kaplinsky e Morris, 2001).

Diante desse cenário, a criação e comercialização de insetos comestíveis se tornou crucial, especialmente porque uma parcela significativa da população, principalmente em países em desenvolvimento, ainda enfrenta dificuldades no acesso a proteínas animais essenciais (Agea *et al.*, 2008; Von Braun, 2010).

Um dos principais desafios futuros será aumentar a disponibilidade de insetos comestíveis e, ao mesmo tempo, reduzir o uso de recursos naturais como o solo, utilizado em larga escala para pastagem e plantio de soja, a água potável consumida na produção pecuária e os insumos energéticos empregados em cadeias de proteína animal (Van Huis, 2015). Além disso, os insetos podem ser cultivados com resíduos orgânicos de baixo valor, o que permite transformar subprodutos agrícolas desperdiçados diariamente em proteínas de alto valor nutricional, alinhando-se à lógica da economia circular (Van Huis e Dunkel, 2017). A adoção de ingredientes derivados de insetos em substituição à farinha de peixe e à soja requer escala industrial, eficiência na conversão alimentar e uso racional de recursos, o que reforça a necessidade de inovação tecnológica e automação no setor (Veldkamp *et al.*, 2012).

Nesse sentido, a ampliação da disponibilidade de insetos como ingrediente para ração se torna ainda mais relevante, considerando que a demanda global por ração pode ultrapassar 1 bilhão de toneladas até 2050 (Makkar, 2018). Além disso, o conhecimento e a conscientização dos produtores sobre o uso de insetos como ingrediente nas rações estão diretamente ligados à disposição em pagar por esse novo tipo de produto. Estudos de viabilidade já demonstraram o potencial dessa utilização em dietas para suínos e aves, destacando a importância de promover a aceitação e o uso dessa alternativa entre os produtores (Veldkamp *et al.*, 2012).

Do ponto de vista estratégico, as empresas que pretendem permanecer competitivas globalmente precisam de alinhamento em suas atividades. No entanto, na prática, a estratégia de engajamento internacional e seu sucesso ainda carecem de clareza para a maioria dos líderes empresariais, especialmente aqueles que operam em economias emergentes e países menos desenvolvidos (Vallina-Hernández *et al.*, 2022). Outras habilidades essenciais, como agilidade e inovação, também são cruciais para operar em ambientes complexos que exigem capacidades de resposta rápida e soluções criativas para abordar questões emergentes (Troilo, 2023).

Além dos aspectos ambientais e econômicos, os insetos também se destacam sob a ótica nutricional. Pesquisas realizadas por Dobermann, Swift e Field (2017) demonstraram que o consumo de carne vermelha está associado à maior probabilidade de acidente vascular cerebral, diabetes, câncer de cólon e câncer de pulmão. Em contrapartida, os insetos apresentam uma composição mais nutritiva e saudável do que os alimentos à base de carne, sendo ricos em proteínas, vitaminas e minerais, com menor teor de gordura saturada. Por isso, são considerados substitutos viáveis da carne, oferecendo uma alternativa sustentável, saudável e econômica para o consumo de proteínas (Kromhout *et al.*, 2016).

No Brasil, a cadeia enfrenta desafios significativos, como a falta de desenvolvimento em financiamento, tecnologia e qualificação de recursos humanos, além de uma cadeia de abastecimento e uma estrutura de fornecedores desorganizadas. Embora as agências reguladoras estejam empenhadas em criar regulamentações para a produção e o uso de insetos para ração animal, os produtos à base de proteínas de insetos ainda não são competitivos em relação às fontes proteicas tradicionais (Gomes *et al.*, 2023).

Empresas brasileiras têm concentrado seus investimentos especialmente na criação da mosca-soldado-negro, cujas larvas apresentam elevado potencial de conversão de resíduos orgânicos em proteína. No entanto, apesar dos avanços obtidos com pesquisas e testes industriais, a produção nacional ainda não atingiu escala suficiente para garantir competitividade econômica em mercados regulados por preço, volume e qualidade (Gomes *et al.*, 2023).

1.2 Objetivos

O objetivo geral desta tese é analisar a cadeia de valor dos insetos comestíveis como fonte sustentável de proteína no Brasil, investigando seu alinhamento com os princípios de sustentabilidade e ecoinovação, por meio do desenvolvimento e da avaliação de indicadores de desempenho. Os objetivos específicos consistem em:

1. Investigar a evolução científica do papel dos insetos como proteína alternativa sustentável, valendo-se do estado da arte para delinear a cadeia de valor dos insetos comestíveis e sua aplicação, tanto para consumo humano quanto para ração animal, em um contexto de ecoinovação;

2. Analisar e diagnosticar a cadeia de valor dos insetos comestíveis no Brasil, empregando o framework SWOT (*Strengths, Weaknesses, Opportunities, Threats*), o Modelo de Negócio Sustentável Canvas e um estudo de caso múltiplo, evidenciando as características da sustentabilidade;

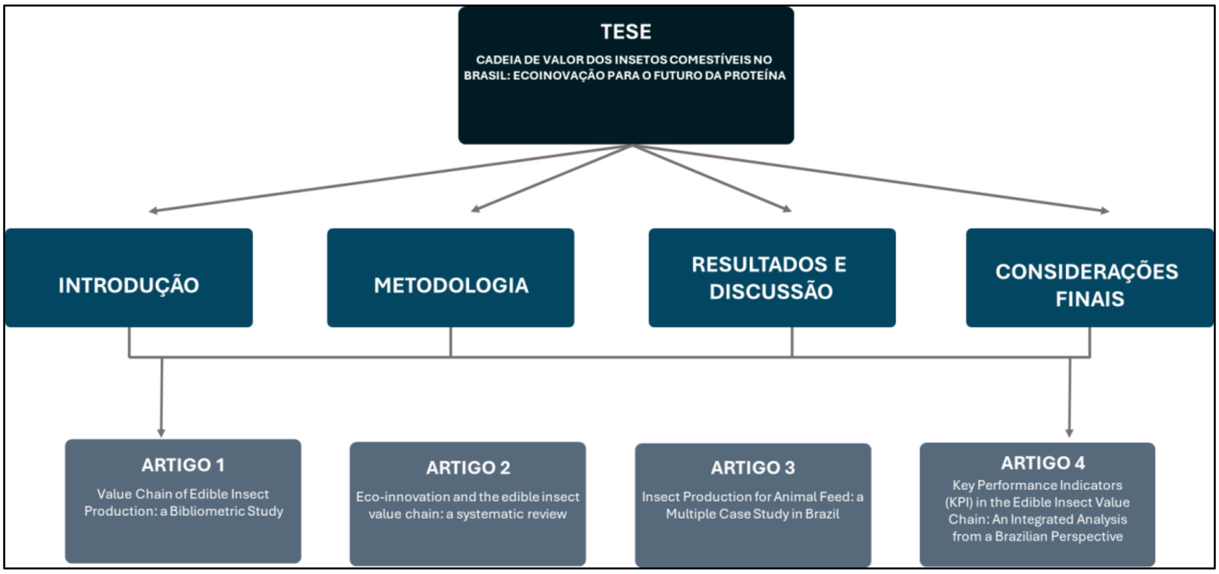
3. Desenvolver e validar indicadores de desempenho da cadeia de valor dos insetos comestíveis no Brasil, analisando suas inter-relações, por meio de abordagem quantitativa com aplicação de correlação e análise fatorial, a fim de identificar fatores críticos que influenciam a expansão sustentável dessa cadeia no contexto nacional.

1.3. Estrutura da tese

A tese é realizada na modalidade por artigos e sua estrutura é demonstrada na Figura 1.

Cada um dos quatro artigos, sendo três já publicados, contribui de forma singular para o tema central da tese, complementando-se mutuamente e fortalecendo a construção da pesquisa principal.

Figura 1: Estrutura da tese na modalidade por artigos



Fonte: Elaborado pela Autora (2024).

a) Artigo 1 - *Value Chain of Edible Insect Production: A Bibliometric Study*

O Artigo 1 constrói a base teórica para compreender como a pesquisa sobre insetos comestíveis está evoluindo globalmente. Ele se conecta diretamente aos objetivos da tese ao mapear a literatura científica sobre a cadeia de valor e os benefícios ambientais da produção de insetos comestíveis, abrangendo tanto o consumo humano quanto o uso na alimentação animal, de forma geral;

b) Artigo 2 - *Eco-innovation and the Edible Insect Value Chain: A Systematic Review*

O Artigo 2 enriquece a tese ao apresentar uma estrutura de sustentabilidade que posiciona a produção de insetos como um modelo de ecoinovação. Ele aborda o objetivo da tese de entender como os sistemas de produção baseados em insetos podem ser mais sustentáveis em comparação com fontes tradicionais de proteína;

c) Artigo 3 - *Insect Production for Animal Feed: A Multiple Case Study in Brazil*

O Artigo 3 oferece dados empíricos e contexto regional, contribuindo para a tese ao mostrar aplicações do mundo real da produção de insetos comestíveis no Brasil. Ele se alinha com o foco da tese no potencial do Brasil para adotar sistemas de produção sustentáveis e destaca áreas para melhoria em regulamentação, tecnologia e desenvolvimento de mercado;

d) Artigo 4 - *Key Performance Indicators (KPI) in the Edible Insect Value Chain: An Integrated Analysis from a Brazilian Perspective*

O Artigo 4 aprofunda a contribuição da tese ao aplicar métodos quantitativos na análise da cadeia de valor dos insetos comestíveis no Brasil, com ênfase nos produtores vinculados à Associação Brasileira dos Criadores de Insetos Alimentícios (ASBRACIA). A partir do desenvolvimento e da validação de indicadores de desempenho, o estudo examina as inter-relações entre variáveis operacionais e estratégicas ao longo da cadeia. Por meio da correlação e da análise fatorial, são identificados pontos críticos e áreas de maior geração de valor, revelando fatores determinantes para a eficiência e a sustentabilidade dos processos produtivos. Essa abordagem empírica e estatística reforça o objetivo central da tese de mensurar, estruturar e otimizar cadeias produtivas de insetos.

Todos os artigos encontram-se integralmente apresentados em formato anexo ao final desta tese. A pesquisa foi aprovada pelo Comitê de Ética em Pesquisa da Universidade Paulista (CEP - UNIP), conforme parecer consubstanciado nº 7.255.655.

2. FUNDAMENTAÇÃO TEÓRICA

Diante dos desafios globais relacionados à segurança alimentar, às mudanças climáticas e à sustentabilidade dos sistemas produtivos, os insetos comestíveis têm ganhado destaque como alternativa viável e estratégica à produção convencional de proteína. Esta fundamentação teórica aborda os principais aspectos que sustentam essa perspectiva, reunindo evidências sobre os impactos ambientais da produção de alimentos, os benefícios nutricionais e ecológicos dos insetos, bem como as oportunidades e os entraves para o desenvolvimento da cadeia de valor.

2.1 Mudanças climáticas, segurança alimentar e o cultivo de insetos

O aquecimento global tornou-se um desafio mundial crítico, impactando diretamente a agricultura e a segurança alimentar. Esse fenômeno tem desencadeado eventos climáticos que afetam a sustentabilidade alimentar (Nyangea *et al*., 2020), tornando-se foco de interesse de pesquisadores em diversas áreas, que buscam soluções para mitigar seus efeitos negativos, muitas vezes irreversíveis (Simon *et al*., 2019). Como parte dessas estratégias de adaptação, em 2015, 195 países e a União Europeia assinaram o primeiro acordo climático global, comprometendo-se a limitar o aumento da temperatura do planeta a menos de 2°C acima dos níveis pré-industriais, com o objetivo de reduzir os impactos das mudanças climáticas.

O relatório *The State of Food Security and Nutrition in the World* (Nações Unidas Brasil, 2024) indica que aproximadamente 733 milhões de pessoas enfrentaram fome em 2023, o que equivale a uma a cada onze pessoas no mundo, e, mais especificamente, uma a cada cinco pessoas na África. Simion *et al.,* (2019) apontam que os riscos alimentares são globais, e o acesso aos alimentos tornou-se um desafio mundial, não apenas para os países em desenvolvimento, mas uma prioridade econômica para todas as nações. O aumento populacional, o aquecimento global, o uso insustentável de recursos alimentares, os desastres naturais e os conflitos armados são alguns dos fatores que têm agravado a insegurança alimentar. De acordo com a FAO (2023), embora a prevalência de subnutrição na Ásia seja menos da metade do que da África, a Ásia abriga 402 milhões de pessoas enfrentando a fome, representando 55% do total de pessoas subnutridas em 2022, enquanto cerca de 282 milhões (38%) das pessoas subnutridas vivem na África e cerca de 43 milhões (6%) na América Latina e no Caribe.

Para contribuir na redução desses impactos, Van Huis e Oonincx (2017) sugerem algumas medidas, como a diminuição da demanda por produtos pecuários, a redução das emissões de esterco e o aumento do sequestro de carbono em pastagens. Dado que um quarto de todas as emissões antropogênicas de gases de efeito estufa provém da produção global de alimentos, o consumo de insetos surge como uma alternativa mais sustentável e saudável para o consumo de proteína animal (Miglietta *et al*., 2015). As mudanças climáticas e ambientais têm aumentado o interesse por esse consumo, principalmente em países africanos, onde a coleta de insetos comestíveis é uma prática diária. Proteger essas tradições é crucial para garantir a disponibilidade desses recursos para as gerações futuras (Musundire *et al*., 2021).

Os insetos comestíveis podem desempenhar um papel fundamental na segurança alimentar, oferecendo uma solução para a carência de nutrientes, especialmente como fonte de proteína. Além disso, sua produção emite quantidades significativamente menores de gases de efeito estufa, demanda menos terra e apresenta uma alta eficiência de conversão alimentar. Os insetos também têm o potencial de substituir, em parte, os ingredientes utilizados em rações para gado e aquicultura, liberando, assim, para o consumo humano, os cereais destinados à ração animal (Van Huis, 2013).

Nos últimos anos, cientistas de todo o mundo tem apresentado análises e descobertas sobre o potencial dos insetos como nova fonte de proteína, tanto para consumo humano quanto para ração animal, bem como para analisar os diferentes estágios da cadeia de valor. Um marco importante desse interesse foi o simpósio realizado em 2018 na Holanda, que celebrou dez anos de pesquisa na área (Lakemond *et al*., 2019).

Segundo Odongo *et al*., (2018), estudos de mercado também indicam oportunidades promissoras como potencial de geração de renda local e substituição de fontes tradicionais de proteína, destacando a cadeia de valor e as oportunidades de mercado, como alta demanda com oferta insuficiente, expansão para mercados urbanos e internacionais, e marketing cultural e gastronômico. Os resultados de sua pesquisa mostraram que o comércio de insetos comestíveis oferece uma fonte alternativa de subsistência para coletores, vendedores ambulantes e comerciantes em áreas rurais e urbanas. A pesquisa revelou que o preço de um quilo de insetos comestíveis era de US$ 3,00, comparado ao preço da carne bovina (US$ 3,50) e do peixe (US$ 1,95).

Desde 25 de novembro de 2015, a União Europeia (UE), por meio do Regulamento 2015/2283, passou a considerar os insetos como novos alimentos, submetendo-os a um procedimento de autorização mais simples e eficiente. Esse regulamento permite a comercialização de alimentos à base de insetos em todo o território da UE, deixando claro que os insetos podem ser consumidos inteiros ou em partes (Ramos-Elorduy, 2006; Araújo, 2006).

No entanto, essa determinação não é aplicada na maioria dos países, onde a falta de regulamentação é um desafio. Em muitos casos, os tomadores de decisão ainda veem os insetos como pragas, e não como alimentos em potencial. Isso afeta diretamente os empreendedores do setor, que enfrentam dificuldades para comercializar e desenvolver produtos, além de lidar com problemas como exploração inadequada, cobranças excessivas, monopólios sobre intermediação e má conservação dos recursos naturais (Ramos-Elorduy, 2006; Niassy *et al.*, 2018).

2.2 Ecoinovação e a cadeia de valor dos insetos comestíveis

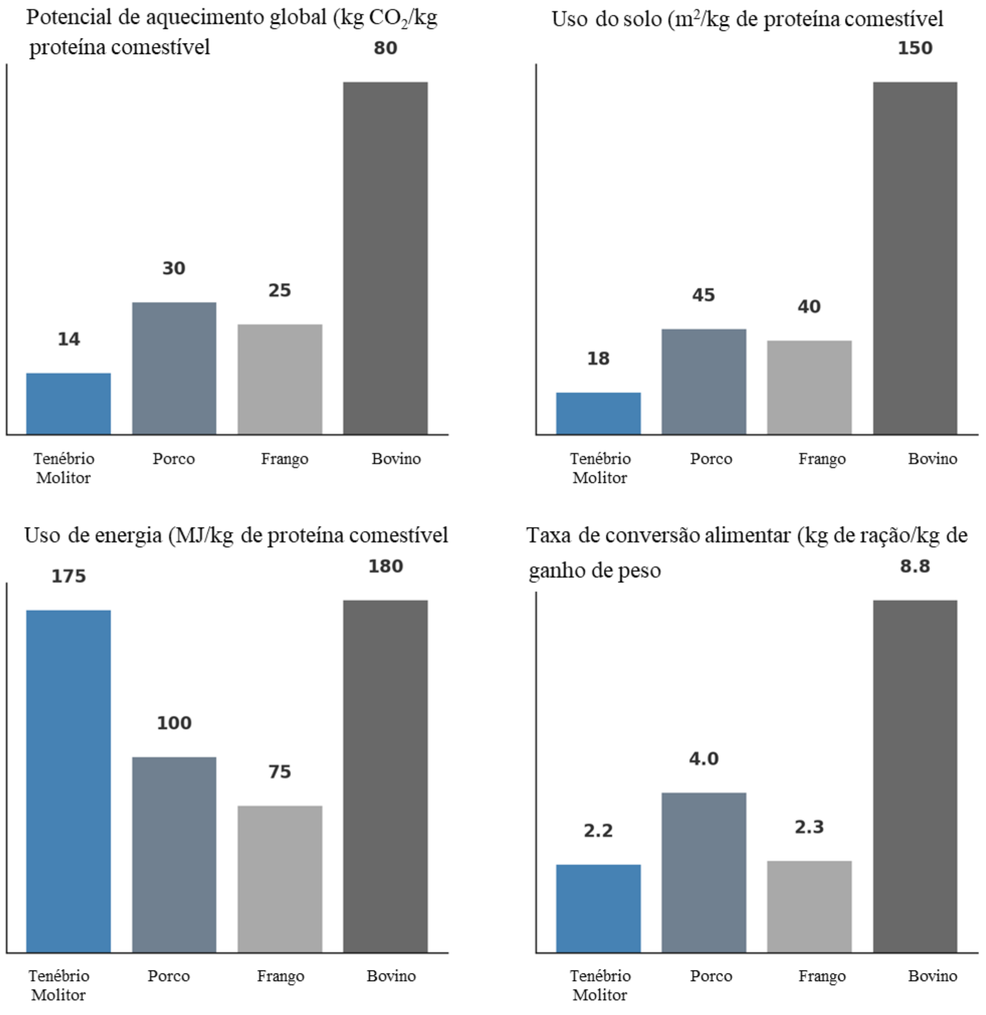
Ecoinovação, abreviação de inovação ambiental, tem como objetivo principal reduzir os impactos negativos das inovações no meio ambiente natural (Reid e Miedzinski, 2008). Entre suas principais vantagens estão a diminuição do impacto ambiental, o aumento da eficiência e a melhoria da competitividade (Mady *et al.*, 2023). O conceito de ecoinovação é bastante amplo, abrangendo desde o controle da poluição até a redução de resíduos (Kemp e Pearson, 2007). Além disso, o critério essencial para classificar uma inovação como ecoinovação é de que seu uso seja menos prejudicial ao meio ambiente em comparação com alternativas convencionais. Essas inovações podem surgir de soluções novas ou aperfeiçoadas, aplicadas ao longo de todo o ciclo de vida de um produto ou serviço, desde sua concepção até o descarte (Reid e Miedzinski, 2008).

No contexto das cadeias produtivas, as evidências sugerem que os maiores ganhos em eficiência de recursos tendem a ocorrer nas fases iniciais da produção ou em suas etapas intermediárias, com uma redução na eficiência ao longo da cadeia de suprimentos (Reid e Miedzinski, 2008). De acordo com o conceito de Kemp e Pearson (2007), ecoinovação é a produção, assimilação ou exploração de um produto, processo produtivo, serviço, método de gestão ou negócio que seja novo para a organização, seja ele desenvolvido ou adotado, e que, ao longo de seu ciclo de vida, contribua para a redução de riscos ambientais, poluição e outros impactos negativos relacionados ao uso de recursos, incluindo energia. Com o aumento das preocupações ambientais, o esgotamento dos recursos ecológicos e os crescentes impactos ambientais, o estudo da ecoinovação tem ganhado relevância (Riaz *et al*., 2023). Um exemplo de ecoinovação pode ser observado na cadeia de valor associada ao consumo de insetos, tanto para alimentação humana quanto para ração animal (Gomes *et al.* 2023).

Nesse sentido, Kemp e Pearson (2007) propuseram uma classificação de ecoinovações que inclui tecnologias ambientais, inovações organizacionais voltadas ao meio ambiente, inovações de produtos e serviços com benefícios ambientais, e inovações de sistemas verdes. A cadeia de valor relacionada ao consumo de insetos, tanto para alimentação humana quanto para ração animal, enquadra-se na categoria de inovações de sistemas verdes (Gomes *et al.* 2023). Esse tipo de inovação ambiental sugere uma maior probabilidade de gerar benefícios sociais positivos, resultantes de um compromisso mais profundo com práticas sustentáveis de longo prazo (Berrone *et al*., 2013).

Além disso, o uso de farinha de insetos na alimentação animal apresenta vantagens ambientais expressivas em comparação às fontes convencionais de proteína, como a farinha de soja e a carne bovina (Oonicx e De Boer, 2012; Wilkinson, 2011). Esses dados encontram-se representados na Figura 2, que reforça o papel dos insetos comestíveis como alternativa sustentável.

Figura 2 - Comparação do impacto ambiental e da eficiência alimentar entre diferentes fontes de proteína animal



Nota: Os valores apresentados na tabela correspondem aos valores mínimos relatados na literatura por Oonincx e De Boer (2012) para as métricas de potencial de aquecimento global, uso da terra e uso de energia. A taxa de conversão alimentar foi extraída do estudo de Wilkinson (2011).

Fonte: Adaptado de Oonincx e De Boer (2012) e Wilkinson (2011).

O *Tenebrio molitor* tem potencial de aquecimento global estimado em apenas 14 kg de CO_2 equivalente por quilo de proteína comestível, enquanto o valor correspondente para bovinos é de 80 kg de CO_2. A ocupação de solo também é significativamente menor (18 m²/kg, frente a 150 m²/kg para bovinos), assim como a conversão alimentar: 2,2 kg de alimento por quilo de ganho de peso, contra 8,8 kg nos bovinos (Oonicx e De Boer, 2012; Wilkinson, 2011).

2.3 Produção de insetos para consumo humano

De acordo com Lähteenmäki-Uutela *et al.* (2021), em muitas partes da América do Norte, os insetos foram historicamente incorporados à cultura alimentar. A criação de insetos destinados à produção de alimentos e rações começou a aumentar a partir de 2012. A moderna indústria de insetos deriva de empresas que já cultivavam grilos e larvas de farinha para ração animal. Para evitar altos custos de mão de obra, muitas fazendas de insetos americanas e canadenses investiram em automação pelo emprego de robôs, sensores e big data.

A aceitação do consumo de insetos varia entre os países e é influenciada por fatores culturais e sociais. Estudos que comparam o valor nutricional dos insetos com proteínas convencionais podem contribuir para aumentar essa aceitação (Vantomme, 2015; Patel *et al.*, 2019). Em países em desenvolvimento, como os da África Subsaariana, a entomofagia desempenha um papel crucial na segurança alimentar e na geração de renda, embora ainda careça de reconhecimento governamental e de estratégias de conscientização da população sobre seu valor (Musundire *et al.*, 2021).

Por outro lado, em regiões desenvolvidas, como Europa e Estados Unidos, a indústria de insetos comestíveis está em rápida expansão. Alguns países já estabeleceram protocolos rigorosos de produção para garantir a segurança alimentar (Ayieko *et al.*, 2021; Kim *et al.*, 2019; Van Huis e Dunkel, 2017). Apesar dos crescentes interesse e consumo, ainda há necessidade de mais pesquisas sobre os aspectos de segurança e nutrição desses alimentos (Errico *et al.*, 2022).

Insetos comestíveis são uma nova forma de alimento que apresenta diversos benefícios para enfrentar a deficiência de proteína e energia causada pelo rápido crescimento da população mundial. Utilizar insetos como alimento pode impulsionar a economia e ter um impacto positivo no meio ambiente e na sobrevivência humana (Papastavropoulou *et al.*, 2023). Tecnologias avançadas também são necessárias para garantir a segurança no consumo, pois os insetos podem ser suscetíveis à contaminação durante a coleta e a venda (Mumbula *et al.*, 2022).

Cerca de 2.000 espécies de insetos são consumidas em todo o mundo, e as empresas alimentícias agora incorporam ingredientes de insetos em barras de proteína, salgadinhos, biscoitos, massas e até mesmo confeitos (*Mordor Intelligence*, 2024). Formatos processados frequentemente melhoram a aceitação do consumidor, mascarando características sensoriais que, de outra forma, poderiam desencorajar novos compradores (Li *et al.*, 2023).

Além disso, o interesse dos consumidores ampliou o portfólio global de espécies criadas, incluindo gafanhotos, formigas, bichos-da-seda e cigarras, estimulando novos investimentos e a diversificação de produtos. Ao mesmo tempo, o aumento dos preços das fontes convencionais de proteína acelerou a busca por alternativas. Os insetos ganharam popularidade entre atletas e entusiastas do fitness que preferem proteínas de alta qualidade com menor pegada ambiental, uma tendência emergente que impulsionou o crescimento do mercado (*Fortune Business Insights*, 2025).

2.4 Produção de insetos para ração animal

O valor nutricional dos insetos é excepcional e os nutrientes primários incluem proteínas, óleos, vitaminas, minerais e açúcares, todos cruciais para a saúde e o desenvolvimento humano (Zhou *et al.*, 2022). Os insetos têm uma alta capacidade em todos os estágios do ciclo de vida como fonte de valor nutricional e são uma fonte significativa de proteína animal, contêm aminoácidos essenciais, minerais (K, Na, Ca, Cu, Fe e Zn) e ácidos graxos insaturados. A taxa de assimilação das proteínas dos insetos é de 76-82%. Os carboidratos dos insetos são compostos principalmente de quitina, que está presente em uma faixa de concentração de 2,7 mg a 49,8 mg/kg de massa seca (Gorbunova e Zakharov, 2021).

Os insetos mais promissores para a produção industrial de ração são a mosca-soldado-negro (*Hermetia illucens*), a mosca doméstica (*Musca domestica*) e o verme da farinha amarela (*Tenebrio molitor*). Essas espécies têm sido estudadas por seu valor nutricional, que é significativo em todos os estágios do ciclo de vida (Veldkamp *et al.*, 2012).

As larvas de *Hermetia illucens*, em particular, têm recebido atenção especial devido à sua capacidade de transformar resíduos orgânicos em biomassa rica em nutrientes. A produtividade aumenta consideravelmente quando temperatura, densidade larval e composição do substrato são otimizadas, parâmetros atualmente considerados pontos críticos de alavancagem para a ampliação de cadeias de fornecimento de proteína sustentável (Nayak *et al.*, 2024).

Shah *et al.* (2022) avaliaram as composições químicas e o valor nutritivo desses insetos, e encontraram uma composição de 41,1% a 43,6% de proteína bruta nas larvas de mosca-soldado-negro, além de minerais como cálcio e fósforo. Da mesma forma, as larvas de mosca doméstica também são ricas em energia, proteínas e micronutrientes, como cobre, ferro e zinco, além de aminoácidos essenciais e ácidos graxos. Elas são uma fonte acessível e barata de proteína animal de alta qualidade, sendo mais fáceis de obter do que outras fontes de proteína (St-Hilaire *et al.*, 2007).

A adoção bem-sucedida de insetos em larga escala depende da produção economicamente viável, durante todo o ano, de biomassa uniforme e de alta qualidade. Técnicas que convertem insetos em farinhas proteicas estáveis são essenciais para a padronização dos produtos e a garantia da segurança alimentar; sem esses aprimoramentos, a competitividade e a escalabilidade da criação de insetos continuarão limitadas (Van Huis, 2013).

Nesse contexto, é fundamental compreender as etapas do processo de produção e processamento de insetos comestíveis. O Quadro 1 resume essas etapas de forma estruturada, desde a produção de insumos até a distribuição, destacando pontos críticos para a eficiência produtiva e a padronização de qualidade.

Quadro 1 – Etapas da produção e processamento de insetos comestíveis

Módulo	Estágios da produção	Descrição
Produção de ração primária	Matérias-primas	Entrada, mistura e armazenamento do substrato alimentar para os insetos.
	Processamento de ingredientes	Seleção e preparo dos ingredientes conforme composição nutricional requerida.
Fase de crescimento larval	Produção de ovos e colônias	Produção de colônias adultas e postura de ovos.
	Manejo da alimentação	Distribuição e gerenciamento do alimento para as larvas.
	Controle climático	Controle de temperatura, umidade, ventilação e confinamento.
	Gestão sanitária	Boas práticas de higiene e controle de pragas.
Processamento dos insetos	Separação	Separação das larvas do substrato residual (peneiramento ou migração natural).
	Abate	Tratamentos térmicos (escaldamento, congelamento) para preservar valor nutritivo.
	Processamento	Moagem e extração de derivados (proteína, óleo, quitina) por métodos físicos, químicos ou bioquímicos.
	Embalagem	Padronização para evitar contaminação e garantir rotulagem adequada.
Biomassa residual	Produção de composto	Uso do resíduo (frass) para fertilizantes, evitando compostagem tradicional.
Distribuição	Armazenamento e comercialização	Transporte, estocagem e venda do produto final.

Fonte: Adaptado de Costa *et al.* (2021), Spykman *et al.* (2021) e *International Platform of Insects for Food and Feed* – IPIFF (2022).

Essa organização em módulos destaca como a eficiência geral da cadeia de valor depende da integração entre todas as etapas. A padronização e o controle sanitário são essenciais não apenas para garantir a qualidade do produto, mas também para aumentar a confiança dos mercados consumidores e facilitar a inserção em cadeias agroindustriais mais amplas.

Na Europa, o mercado de insetos para rações de animais aquáticos já representa cerca de metade do mercado total de rações de insetos para animais. A previsão é de que esse setor cresça 75% nos próximos seis anos, com os criadores europeus produzindo atualmente aproximadamente 1.000 toneladas de rações à base de proteínas de insetos (Veldkamp *et al*., 2022). Desde 2021, a União Europeia permitiu o uso de proteínas animais processadas (PAPs) em rações para aves e suínos, marcando um avanço importante para a sustentabilidade na produção de proteínas e abordando preocupações ambientais de longo prazo (Veldkamp *et al*., 2022; Lähteenmäki-Uutela *et al*., 2021).

No Brasil, a cadeia de produção de insetos ainda está nos estágios iniciais de desenvolvimento, enfrentando desafios significativos em termos de financiamento, tecnologia e qualificação de mão de obra. Entretanto, agências reguladoras começam a promover regulamentações específicas para a produção e uso de insetos em rações animais, incentivando o crescimento do setor e atraindo novos participantes para essa inovação (Oliveira *et al*., 2023).

A mosca-soldado-negro tem recebido destaque por sua capacidade de converter resíduos alimentares em produtos proteicos e lipídicos, promovendo a sustentabilidade e a redução de resíduos (Santos, 2023). Esse último autor também investigou como a dieta influencia a composição nutricional das larvas de mosca-soldado-negro, enquanto Silva *et al*., (2018) criaram uma unidade demonstrativa para a decomposição de resíduos orgânicos. Além disso, Teixeira Filho (2023) sugeriu a produção em massa de mosca-soldado-negro como solução para o descarte de resíduos sólidos e geração de proteína animal, alcançando uma redução de 83,75% no volume de resíduos orgânicos utilizados como substrato alimentar.

A cadeia de suprimentos agroalimentar, que inclui todas as etapas da produção agrícola, desde o cultivo até o consumo final, é particularmente vulnerável devido à perecibilidade dos produtos, sazonalidade, mudanças climáticas e requisitos de qualidade e segurança (Esposito *et al*., 2020 e Mehmood *et al*., 2021). Nesse contexto, a cadeia produtiva de insetos comestíveis opera como uma extensão da cadeia agroalimentar, enfrentando desafios semelhantes (Gomes *et al,* 2023).

2.5 Desenvolvimento e consolidação da cadeia de valor dos insetos comestíveis

Embora os alimentos à base de insetos apresentem um potencial real como fonte sustentável de proteína, o setor ainda enfrenta diversos obstáculos antes de se firmar plenamente. Superar esses desafios exige colaboração entre todos os elos da cadeia, de modo que a rentabilidade e a responsabilidade ambiental avancem em conjunto (Li *et al.*, 2023).

Enxergar o setor por meio da estrutura de cadeia de valor proposta por Kaplinsky e Morris (2001) facilita a identificação de onde o valor é criado e onde os gargalos retardam o progresso, percepções que podem aprimorar a competitividade no cenário global. Bermúdez-Serrano (2020) observa que a configuração da cadeia varia conforme o contexto: em algumas regiões, segue tradições antigas, enquanto em outras ainda está em formação. De forma geral, no entanto, quatro estágios centrais tendem a se repetir:

1. Fornecimento de insumos: fornecedores de subprodutos orgânicos e ingredientes especializados para alimentação;
2. Produção de insetos: que vai desde a coleta silvestre e unidades familiares até fazendas industriais de grande escala;
3. Processamento: empresas que transformam insetos em ingredientes intermediários ou produtos finais para os mercados de alimentos, rações, fármacos e cosméticos;
4. Distribuição e consumo: canais de varejo (feiras, supermercados, restaurantes, e-commerce) e os consumidores finais, locais ou internacionais.

Mapear esses estágios e seus pontos de interação possibilita racionalizar operações, reduzir custos e elevar a qualidade dos produtos. Uma visão sistêmica também estimula a especialização dos produtores e a adoção de inovações tecnológicas, ambos fatores críticos para construir uma cadeia de valor eficiente, sustentável e competitiva em escala global (Kaplinsky e Morris, 2001).

3. METODOLOGIA

Considerando a estrutura da tese por artigos, a abordagem metodológica adotada combina diferentes métodos qualitativos e quantitativos, aplicados de forma articulada aos objetivos específicos e às questões de pesquisa de cada estudo. Além disso, os Artigos 1 e 2 utilizaram, respectivamente, análise bibliométrica e revisão sistemática para fundamentar teoricamente o trabalho, permitindo mapear avanços científicos, identificar lacunas relevantes e consolidar conceitos-chave sobre sustentabilidade, cadeia de valor e ecoinovação. Esse arcabouço teórico serviu de base estruturante para o desenvolvimento das investigações empíricas apresentadas nos Artigos 3 e 4.

A seguir, são detalhados os métodos utilizados em cada artigo e como estes se articulam com os objetivos específicos da pesquisa.

3.1 Artigo 1 - *Value Chain of Edible Insect Production: A Bibliometric Study*

Conexão com o objetivo específico: esse artigo contribui diretamente para o primeiro objetivo específico da tese, ao mapear a evolução científica e delinear o escopo da cadeia de valor dos insetos comestíveis por meio de uma análise da literatura acadêmica sobre o tema.

Método: pesquisa bibliográfica

Objetivo geral: analisar a evolução das publicações científicas e o papel dos insetos comestíveis na produção sustentável para alimentação humana, utilizando, em particular, a análise bibliométrica para compreender a cadeia de valor dos insetos comestíveis.

Questão de pesquisa: o estudo busca responder como a pesquisa científica sobre insetos comestíveis evoluiu e como eles podem contribuir para atender à necessidade global de fontes de proteína sustentáveis.

O estudo empregou análise bibliométrica usando o banco de dados Web of Science para coletar e analisar publicações de 2006 a 2021. Uma categorização qualitativa foi aplicada, com foco em tópicos como "insetos como alimento e ração", "ciência da alimentação" e "humanidades e ciências sociais veterinárias". A análise incluiu uma seleção sistemática de artigos com base em sua relevância para a questão de pesquisa. Com a metodologia bibliométrica aplicada, é possível observar e analisar vários aspectos-chave do panorama da pesquisa sobre insetos comestíveis.

1. Tendências em publicações científicas: a metodologia permitiu acompanhar a evolução da pesquisa ao longo do tempo, identificando períodos de crescimento ou declínio na publicação de artigos relacionados a insetos comestíveis;

2. Principais áreas de pesquisa: ao categorizar os tópicos, como "insetos como alimento e ração" ou "ciência dos alimentos", foi possível avaliar quais áreas estão recebendo mais atenção;

3. Tópicos emergentes: permitiu a identificação de temas de pesquisa novos e emergentes no campo de insetos comestíveis, fornecendo insights sobre direções futuras;

4. Impacto na sustentabilidade: foi possível analisar o papel dos insetos comestíveis no atendimento às necessidades globais de proteína e na contribuição para a sustentabilidade, principalmente por meio da redução dos impactos ambientais.

3.2 Artigo 2 - *Eco-innovation and the Edible Insect Value Chain: A Systematic Review*

Conexão com o objetivo específico: esse artigo também responde diretamente ao primeiro objetivo específico da tese, ao analisar a cadeia de valor de insetos comestíveis como ecoinovação e avaliar sua aplicação em sistemas produtivos sustentáveis, tanto para consumo humano quanto animal.

Método: revisão sistemática

Objetivo geral: conduzir uma revisão sistemática de pesquisas relacionadas ao consumo de insetos por humanos e ao seu uso como ração animal, no contexto da ecoinovação. O estudo visa explorar como os insetos comestíveis se encaixam em práticas sustentáveis e sua contribuição para abordar os desafios ambientais e de segurança alimentar.

Questão de pesquisa: O estudo busca responder se a cadeia de valor associada ao consumo de insetos para alimentação humana e ração animal pode ser considerada uma ecoinovação.

Por meio da metodologia aplicada, foi possível identificar, analisar e interpretar evidências disponíveis relacionadas à cadeia de valor de insetos comestíveis, conforme publicações em bancos de dados respeitáveis, como Web of Science (WoS) e Scopus. A busca foi conduzida usando o operador lógico 'AND' para combinar os termos “insetos comestíveis” e “cadeia de valor”.

A revisão sistemática foi focada em uma seleção de 26 artigos não duplicados, oferecendo uma perspectiva global sobre o consumo de insetos comestíveis e seu papel em sistemas alimentares sustentáveis.

Essa abordagem assegurou a coleta e a análise de evidências de pesquisa primária, garantindo objetividade e reprodutibilidade. O método utilizado permitiu insights abrangentes sobre a integração dos insetos comestíveis em práticas de ecoinovação, destacando os principais resultados do cenário de pesquisa global.

Com a metodologia de revisão sistemática aplicada é possível observar e analisar vários aspectos-chave:

1. Tendências em ecoinovação: ao revisar artigos de bancos de dados como Web of Science e Scopus, o estudo destacou como a cadeia de valor de insetos comestíveis se encaixa no conceito mais amplo de ecoinovação. Foi possível avaliar como a produção de insetos comestíveis aborda os desafios ambientais, incluindo eficiência de recursos, redução de resíduos e redução de gases de efeito estufa;

2. Panorama global de pesquisa: a metodologia permitiu explorar como a pesquisa sobre o consumo de insetos comestíveis evoluiu globalmente. Ela identificou diferenças regionais, mostrando quais países estão liderando na integração de insetos comestíveis em práticas sustentáveis e ecoinovação;

3. Temas-chave e áreas de foco: a revisão sistemática ajudou a identificar os principais temas de pesquisa, como impactos ambientais do consumo de insetos, avanços tecnológicos e implicações políticas. Foi possível analisar como esses temas contribuem para a segurança alimentar e a sustentabilidade;

4. Redes de colaboração: a metodologia mapeou padrões de colaboração entre autores, instituições e países, mostrando dinâmicas e parcerias globais de pesquisa;

5. Aplicações práticas das descobertas: por meio da síntese dos artigos revisados, também foi possível analisar como o conhecimento obtido na pesquisa sobre insetos comestíveis está sendo aplicado em contextos do mundo real, como o

desenvolvimento de práticas ecoinovadoras na agricultura e nos sistemas alimentares;

6. Política e regulamentação: por fim, a revisão sistemática destacou o papel das políticas e regulamentações na formação da cadeia de valor dos insetos comestíveis, enfatizando a necessidade de maior desenvolvimento legislativo para apoiar o crescimento sustentável desse setor.

3.3 Artigo 3 - *Insect Production for Animal Feed: A Multiple Case Study in Brazil*

Conexão com o objetivo específico: esse artigo responde ao segundo objetivo específico da tese ao analisar e diagnosticar a cadeia de valor de insetos comestíveis no Brasil, utilizando análise SWOT e modelo Canvas para evidenciar características de sustentabilidade e um estudo de caso múltiplo, destacando seus atores, práticas sustentáveis e desafios enfrentados pelas empresas do setor.

Método: estudo de caso

Objetivo geral: analisar a cadeia de valor de insetos comestíveis para ração animal no Brasil usando a análise SWOT e o Modelo de Negócio Sustentável Canvas, enfatizando características de sustentabilidade.

Objetivos específicos: identificar os principais atores da cadeia de valor de insetos comestíveis no Brasil e destacar os benefícios e desafios de sustentabilidade associados ao uso de insetos como fonte de proteína na ração animal.

Questão de pesquisa: o estudo busca responder como é a atual condição organizacional das empresas de insetos comestíveis para ração animal no Brasil.

A pesquisa adotou uma abordagem estruturada para oferecer uma visão detalhada dos aspectos estratégicos e operacionais da cadeia de valor de insetos comestíveis para ração animal no Brasil, seguindo as etapas descritas a seguir:

a) Revisão da literatura e pesquisa bibliográfica: o primeiro passo consistiu em uma ampla revisão da literatura sobre a produção de insetos para ração animal, com o objetivo de estabelecer a base teórica e identificar os principais conceitos relacionados à sustentabilidade, inovação e cadeia de valor dos insetos comestíveis. As fontes foram obtidas de bancos de dados acadêmicos, relatórios e estudos focados em ração animal à base de insetos e em práticas sustentáveis;

b) Seleção de casos: duas empresas envolvidas na produção de insetos para ração animal no Brasil foram selecionadas para o estudo de caso: Alpha Company, a mais experiente das duas, com sete anos de mercado, e Beta Company, uma empresa mais nova que se concentra fortemente em tecnologia e técnicas avançadas de produção;

c) Entrevistas semiestruturadas: o principal método de coleta de dados envolveu a realização de entrevistas semiestruturadas com as principais partes interessadas de ambas as empresas. As perguntas foram elaboradas para coletar informações sobre seus processos de produção, estratégias de sustentabilidade, modelos de negócio e desafios que enfrentam na cadeia de valor dos insetos. Foram conduzidas entrevistas para coletar insights qualitativos que não apenas abordassem as questões da pesquisa, mas também fornecessem perspectivas detalhadas sobre os papéis das empresas na cadeia de valor;

d) Análise SWOT: uma análise SWOT foi aplicada a ambas as empresas para avaliar suas posições atuais na cadeia de valor de insetos comestíveis no Brasil;

e) Modelo de Negócio Sustentável Canvas: o *Sustainable Business Model Canvas* foi aplicado para avaliar os modelos de negócio das empresas Alfa e Beta Company, permitindo uma análise de como essas empresas criam, entregam e capturam valor, com foco na sustentabilidade. A ferramenta considerou elementos como principais parceiros, recursos, relacionamento com clientes e fontes de receita, sempre no contexto de práticas sustentáveis e inovação no setor de insetos comestíveis;

f) Síntese e análise de dados: após a coleta das entrevistas e dos dados específicos dos casos, foi realizada uma análise detalhada. Os dados foram sintetizados para comparar as abordagens das duas empresas em termos de sustentabilidade e inovação na cadeia de valor dos insetos comestíveis. Os resultados da análise SWOT e do modelo de negócio ajudaram a identificar padrões, desafios e oportunidades no setor de ração animal à base de insetos no Brasil.

Com a metodologia de estudo de caso aplicada é possível observar e analisar vários aspectos-chave:

1. Situação atual da cadeia de valor dos insetos no Brasil: por meio dos estudos de casos das empresas Alfa e Beta Company, a metodologia permitiu avaliar o nível de desenvolvimento do setor de produção de insetos comestíveis para ração

animal no Brasil. A análise SWOT contribuiu para evidenciar os pontos fortes e fracos dessas empresas, bem como para identificar oportunidades e ameaças na indústria. Entre os pontos fortes, destaca-se o fato de que a criação de insetos emite menos gases de efeito estufa do que a pecuária convencional e requer menos água para produzir a mesma quantidade de proteína animal, além de permitir o reaproveitamento de resíduos orgânicos como substrato. Entre os pontos fracos, observa-se a existência de proibições legislativas à comercialização de produtos à base de insetos e a limitação do número de empresas ativas no setor. Como oportunidade, destaca-se o potencial dos insetos como fonte eficaz de proteína e gordura, contribuindo para a segurança alimentar com menor impacto ambiental. Por outro lado, entre as ameaças, ressaltam-se os impedimentos culturais à aceitação de insetos na alimentação animal e os riscos associados à presença de resíduos orgânicos potencialmente prejudiciais ou contaminantes;

2. Sustentabilidade e inovação: ao usar o *Sustainable Business Model Canvas*, foi possível analisar como cada empresa integra a sustentabilidade em seus modelos de negócio. Isso inclui entender como elas criam e capturam valor enquanto contribuem para metas ambientais, como a redução de resíduos orgânicos e seu uso na produção de insetos. Também foi possível avaliar seu alinhamento com tendências globais de sustentabilidade e práticas de ecoinovação. A seguir, o Quadro 2 apresenta um comparativo sintético entre os principais elementos dos modelos de negócio sustentáveis adotados pelas empresas Alfa e Beta Company:

Quadro 2 – Comparativo do modelo de negócio sustentável: empresas Alfa Company e Beta Company

Elemento	Empresa Alfa Company	Empresa Beta Company
Proposta de valor	Produção de ração sustentável com foco ambiental e social; reintrodução de resíduos na cadeia.	Eliminar a fome e regenerar o ecossistema com proteína e óleo de insetos.
Segmento de clientes	Revendedores de insetos vivos, tutores de pets, empresas de controle biológico.	Produtores de ração animal e, futuramente, clientes de linha própria de ração.
Canais	Redes sociais, WhatsApp, website em reestruturação.	Website estruturado, e-mail e LinkedIn.
Relacionamento com clientes	Relacionamento próximo e ágil, típico de empresa familiar.	Em desenvolvimento, mas já realiza vendas e mantém presença digital.
Atividades-chave	Criação, separação, pesagem, embalagem e envio de insetos; PeD em alimentação e processamento.	Produção de insetos frescos; transformação de resíduos; construção de planta-piloto.
Recursos-chave	Fórmula de alimentação, conhecimento técnico sobre temperatura e umidade, estrutura própria.	Equipamentos, espaço físico e mão de obra.
Parceiros-chave	Universidades, empresa de proteína orgânica, SEBRAE.	Empresa de compostagem (cofundadora), universidades federais rurais.
Fonte de receita	Venda de insetos vivos para três segmentos; maior margem com pets exóticos.	Receita ainda incipiente; previsão de 80% com venda de farinha de insetos.
Estrutura de custos	Matéria-prima e mão de obra; futuro custo elevado com processamento da ração.	Construção da fábrica, aquisição de equipamentos, energia e manutenção geral.

Fonte: Elaborado pela autora (2025).

3. Desafios e oportunidades: a metodologia destaca os principais desafios, como falta de regulamentação, altos custos de produção e cadeias de suprimentos subdesenvolvidas. Ao mesmo tempo, identifica oportunidades como a crescente demanda por fontes de proteína sustentáveis, que podem impulsionar o crescimento da indústria de ração à base de insetos no Brasil.

4. Estratégias de negócios e competitividade: a análise comparativa das duas empresas forneceu insights sobre diferentes estratégias de negócios dentro da cadeia de valor da produção de insetos. Por exemplo, enquanto a Alpha Company pode confiar na experiência de mercado, a Beta Company pode se concentrar em

tecnologia avançada. A análise permitiu observar como essas diferentes abordagens impactam sua competitividade em um mercado ainda incipiente;

5. Ambiente regulatório e de mercado: a metodologia também permitiu avaliar o cenário regulatório no Brasil e seu impacto no desenvolvimento da cadeia de valor de insetos. A análise SWOT identificou obstáculos regulatórios e potenciais oportunidades de mercado que podem surgir de mudanças em políticas ou no aumento do suporte governamental;

6. Viabilidade econômica: ao examinar custos, recursos e sustentabilidade das empresas, a metodologia forneceu insights sobre a viabilidade econômica da ração animal à base de insetos no Brasil. Isso inclui analisar o potencial de redução de custos e a escalabilidade da produção, que são cruciais para tornar a proteína à base de insetos competitiva em relação às fontes tradicionais;

7. Implicações práticas para a indústria: por fim, os resultados dos estudos de caso e da análise SWOT ofereceram recomendações práticas para melhorar o setor brasileiro de produção de insetos. Elas podem orientar futuros investimentos, pesquisas e formulação de políticas visando escalar a indústria e alcançar maior penetração de mercado.

3.4 Artigo 4 - *Key Performance Indicators (KPI) in the Edible Insect Value Chain: An Integrated Analysis from a Brazilian Perspective*

Conexão com o objetivo específico: esse artigo está alinhado ao terceiro objetivo específico da tese, ao desenvolver e validar indicadores de desempenho da cadeia de valor dos insetos comestíveis no Brasil, identificando suas inter-relações e propondo um modelo analítico que contribua para o fortalecimento e a expansão do setor.

Método: abordagem quantitativa e qualitativa (método misto).

Objetivo geral: desenvolver e validar um conjunto de indicadores-chave de desempenho (KPIs) para mensurar a eficiência produtiva, a competitividade e a sustentabilidade da cadeia de valor de insetos comestíveis no Brasil.

Objetivos específicos: mapear os indicadores mais relevantes ao longo das etapas da cadeia de valor, identificar conexões críticas entre variáveis operacionais e estratégicas, e propor um modelo analítico que contribua para o fortalecimento do setor como alternativa sustentável de proteína.

Questão de pesquisa: o estudo busca descobrir quais KPIs apresentam maior centralidade e interdependência na cadeia de valor dos insetos comestíveis no Brasil, e como essas conexões contribuem para a produtividade sistêmica e a consolidação do setor como fonte sustentável de proteína.

A condução metodológica baseou-se na aplicação do *A Handbook for Value Chain Research* (Kaplinsky e Morris, 2001), para captar a estrutura e a dinâmica da cadeia de valor dos insetos comestíveis no Brasil. A seguir, detalham-se as etapas metodológicas adotadas:

a) Definição da abordagem analítica: a estrutura conceitual da pesquisa foi guiada pelos princípios do *Handbook for Value Chain Research*, que propõe a decomposição da cadeia em dimensões analíticas como: (i) Mapeamento da cadeia de valor; (ii) Segmentação de produtos; e (iii) Acesso aos mercados finais. Essa estrutura orientou a seleção dos indicadores, as etapas de coleta de dados e a posterior análise estatística.

Dimensão 1 - Mapeamento da cadeia de valor: essa seção mapeia o fluxo de materiais, serviços e informações:

- Valores de produção: produção total e lucro, calculados a partir dos custos operacionais autodeclarados;
- Fluxo físico de mercadorias: movimentação tangível de produtos, matérias-primas e componentes ao longo das diferentes etapas da cadeia;
- Fluxo de serviços especializados: o papel desempenhado por consultoria, treinamento e transferência de conhecimento;
- Empregabilidade: tipos de empregos criados e efeitos socioeconômicos mais amplos;
- Destinos de vendas: principais canais de comercialização e padrões de consumo;
- Comércio exterior: atividade de exportação e importação.

Dimensão 2 - Segmentação de produtos: as variáveis revelam como os produtores adaptam as ofertas para grupos de clientes distintos:

- Nichos de mercado: grupos de consumidores que compartilham preferências ou comportamentos;

- Volatilidade do mercado: mudanças na demanda, oscilações de preços e pressão regulatória.

Dimensão 3 - Acesso aos mercados finais: o terceiro bloco explora o posicionamento competitivo:

- Principais compradores: mix de clientes, estrutura de mercado e concentração;
- Dinâmica da função de compra: critérios de seleção de fornecedores e poder de barganha;
- Gestão da cadeia de suprimentos: estratégias de diversificação, construção de relacionamentos e logística;

b) Elaboração e validação do instrumento de pesquisa: inicialmente, foi construído um questionário com 65 itens abertos, elaborado a partir das variáveis sugeridas pelo manual e adaptado à realidade do setor brasileiro. Após revisão com especialistas de uma biofábrica de *Hermetia illucens*, a empresa Beta Company do estudo de caso do Artigo 3, o instrumento foi refinado para conter 33 afirmações fechadas em escala Likert de 5 pontos, além de questões demográficas. Esse processo garantiu validade de conteúdo e adequação à linguagem dos produtores;

c) Pré-teste e ajustes: o questionário final foi submetido a um pré-teste em uma fazenda de *Tenebrio molitor*, a fim de verificar a clareza e aplicabilidade prática das questões. A partir do feedback dos produtores, ajustes de redação e formatação foram realizados, assegurando a compreensão do conteúdo por diferentes perfis de respondentes;

d) Aplicação do questionário e coleta de dados: com o apoio institucional da ASBRACIA, a versão final do instrumento foi distribuída via e-mail aos seus membros, alcançando produtores atuantes em diversas regiões do Brasil. Foram obtidas 17 respostas válidas, representando um recorte significativo da cadeia produtiva emergente;

e) Análise descritiva do perfil dos produtores: inicialmente, foram analisados os dados sociodemográficos e operacionais dos respondentes, incluindo porte das empresas, espécies cultivadas, tipos de produtos comercializados e segmentos de mercado atendidos. Essa etapa permitiu contextualizar os resultados e compreender a diversidade estrutural do setor;

f) Análise de correlação de Spearman: a fim de identificar relações estatísticas entre os indicadores de desempenho, foi aplicada a correlação de Spearman, adequada para dados em escala ordinal (Likert). A análise revelou conexões significativas ($r > 0,7$; $p < 0,05$), permitindo mapear a interdependência entre os elos produtivos e comerciais da cadeia;

g) Análise Fatorial Exploratória (AFE): para reduzir a complexidade dos dados e identificar agrupamentos latentes de variáveis, foi aplicada uma AFE. O procedimento resultou na extração de dois fatores principais: (i) segmentação e alcance de mercado; e (ii) organização interna da cadeia. Esses fatores explicaram conjuntamente 46,2% da variância comum dos dados;

h) Avaliação de centralidade dos indicadores: cada indicador foi avaliado com base na sua centralidade, isto é, na quantidade de conexões estatisticamente significativas que mantinha com os demais. Os indicadores com alta centralidade e altas cargas fatoriais foram considerados os mais estratégicos para a estruturação e o fortalecimento da cadeia de valor;

i) Síntese dos resultados e interpretação integrada: os indicadores mais relevantes foram analisados em detalhe, considerando suas correlações com outras variáveis, a etapa da cadeia em que atuam e suas implicações práticas para produtores, gestores e formuladores de políticas. Essa etapa consolidou a proposta de um painel gerencial de KPIs específicos para o setor de insetos comestíveis no Brasil.

Com a metodologia mista aplicada é possível observar e analisar vários aspectos-chave:

1. Qualidade dos relacionamentos com fornecedores: fortes parcerias com fornecedores estão associadas à redução de custos, regularidade na produção e maior diversificação de canais e clientes. Esse indicador funciona como base para a estabilidade e o crescimento sustentável da cadeia;

2. Efetividade da segmentação de mercado: identificar e atender a nichos específicos impulsiona a expansão territorial, melhora a logística e aumenta a retenção de clientes. Esse fator reforça a importância da inteligência de mercado para o posicionamento estratégico;

3. Precisão na previsão de preços: a capacidade de antecipar variações de preços permite ajustes ágeis na produção e maior controle orçamentário. Em

mercados emergentes, essa habilidade é vital para mitigar riscos e manter a competitividade de monitoramento de mercado e modelagem preditiva, especialmente em cadeias emergentes e sujeitas a mudanças regulatórias;

4. Vantagem competitiva no mercado: mais do que atributos do produto, a vantagem competitiva está ligada a estratégias comerciais, *branding* e canais de venda. A diferenciação nesse contexto exige ações integradas de marketing e relacionamento;

5. Eficiência na transformação em produtos finais: envolve o desempenho nas etapas de processamento, uso de subprodutos e gestão da equipe. Contribui diretamente para aumentar o rendimento, reduzir desperdícios e reforçar práticas sustentáveis.

A estrutura final do processo pode ser analisada na Figura 3.

Figura 3 - Estrutura metodológica: relação entre dimensões, variáveis e estágios da cadeia de valor de insetos comestíveis

Dimensão handbook	Variáveis handbook	Etapas da cadeia de valor	Indicadores
Mapeamento da cadeia Identifica e analisa as variáveis e relações que compõem uma cadeia de valor específica	Valores de produção: quilogramas ou toneladas de produção	Produção e eficiência de custos	Variação da produção Eficiência de custo de produção
	Fluxo físico de mercadorias	Aquisição de insumos alimentares - matéria-prima	Acessibilidade de matérias-primas
		Crescimento dos insetos - produção de larvas semente, administração de ração, controle climático e manejo sanitário	Eficiência do manejo reprodutivo Eficiência do preparo de substrato alimentar Sobrevivência larval inicial Estabilidade climática em unidades de produção Controle sanitário da produção
		Processamento e embalagem - separação, abate, tipo de processamento e embalagem	Eficiência na separação larva-resíduo Eficácia do processo de abate Eficiência da transformação em produtos finais Sustentabilidade de embalagens
		Aproveitamento de subprodutos - produção de composto evitado (frass)	Grau de utilização da biomassa residual Aproveitamento comercial do frass
		Distribuição e logística - armazenamento e venda	Eficiência logística
	Fluxo de serviços especializados	Serviços especializados e consultoria	Impacto de serviços especializados
		Capacitação e desenvolvimento	Eficácia de programas de capacitação
	Empregabilidade	Força de trabalho e diversidade	Diversidade e equidade de gênero na força de trabalho
	Destino das vendas	Expansão de mercado interno	Eficácia da expansão de mercado interno
		Crescimento de clientes	Crescimento e retenção de clientes
	Comércio exterior	Comércio internacional e origem de insumos	Receita proveniente de exportações Relação insumos nacionais vs. importados

Segmentação de produtos Divide o mercado final em grupos ou segmentos distintos, com base em características específicas que diferenciam os consumidores ou as demandas de cada grupo	Nichos de mercado	Posicionamento de mercado	Adaptação a mercados diversificados Efetividade da segmentação de mercado
	Volatilidade do mercado	Gestão de preços	Precisão das previsões de preços
		Competitividade de mercado	Vantagem competitiva no mercado
		Ambiente regulatório	Adaptabilidade a mudanças regulatórias
Acesso aos mercados finais Compreende como os produtores, especialmente em economias em desenvolvimento ou em setores específicos, no caso, o de insetos comestíveis, conseguem competir e se inserir em mercados globais altamente competitivos	Principais compradores	Risco e dependência comercial	Diversificação da base de clientes Vendas para clientes estratégicos
	Dinâmica da função de compra	Estratégias comerciais e canais de venda	Eficácia das estratégias de marketing e vendas Diversificação de canais de venda
	Gestão da cadeia de suprimentos	Gestão de fornecedores	Diversificação da base de fornecedores
		Relacionamento com fornecedores	Qualidade do relacionamento com fornecedores

Fonte: Adaptado de Kaplinsky, R.; Morris, M. *A Handbook for Value Chain Research*. 2001. Com acréscimos da autora (2024).

A Figura 3 apresenta uma visão geral sintética da estrutura metodológica que orientou o desenvolvimento do instrumento de pesquisa e a análise da cadeia de valor de insetos comestíveis no Brasil. Em termos práticos, a tabela vincula cada dimensão do *A Handbook for Value Chain Research* às variáveis examinadas e às etapas de campo definidas para a coleta de dados, exatamente como esse manual sugere. Essas variáveis foram então mensuradas por meio do próprio questionário. A estruturação do trabalho dessa forma permite que o estudo capture detalhes técnicos e de produção, bem como a dinâmica de mercado e de relacionamento, criando uma base sólida para os testes estatísticos subsequentes.

4. RESULTADOS

Esta seção apresenta os principais achados dos quatro artigos que compõem a tese, os quais, de forma complementar, contribuem para o entendimento da cadeia de valor dos insetos comestíveis no Brasil sob diferentes perspectivas metodológicas. Os resultados revelam tendências globais de pesquisa, evidências empíricas sobre sustentabilidade e ecoinovação, desafios enfrentados por empresas brasileiras e indicadores estratégicos que orientam a tomada de decisão no setor. A seguir, os resultados são organizados por artigo, destacando as contribuições específicas de cada estudo para o avanço do conhecimento e para o fortalecimento da cadeia produtiva.

4.1 Resultados do Artigo 1

Artigo 1 - *Value Chain of Edible Insect Production: A Bibliometric Study*

A análise bibliométrica destaca um aumento significativo no interesse global de pesquisa em insetos comestíveis, particularmente após 2015. Esse aumento é refletido no número de publicações acadêmicas indexadas, com destaque para o ano de 2021, que apresentou o maior volume de produção científica. A partir da análise de 50 documentos extraídos da base Web of Science, observa-se a consolidação dos insetos comestíveis como tema emergente, relacionado às demandas por soluções sustentáveis e alternativas proteicas.

A análise revelou três agrupamentos principais que orientam os temas mais estudados: (i) insetos como alimento e ração; (ii) aspectos ligados à ciência de alimentos; e (iii) interações com as ciências humanas, sociais e veterinárias. Esses agrupamentos evidenciam a diversidade de abordagens e o caráter multidisciplinar da pesquisa sobre insetos comestíveis.

O estudo bibliométrico também identificou lacunas importantes no campo, reforçando o papel estratégico dos insetos na segurança alimentar, na sustentabilidade ambiental e na inovação em sistemas alimentares. A cadeia de valor dos insetos envolve múltiplos atores e desafios regulatórios, o que demanda maior integração entre ciência, política e mercado. A ausência de normas específicas em diversos países, incluindo o Brasil, é apontada como um entrave à formalização e à expansão comercial do setor.

Por fim, o estudo aponta que a pesquisa contínua é essencial para avançar nas estruturas regulatórias necessárias para dar suporte à comercialização de insetos comestíveis e promover sua aceitação como uma solução viável para a deficiência de proteína.

4.2 Resultados do Artigo 2

Artigo 2 - *Eco-innovation and the Edible Insect Value Chain: A Systematic Review*

A revisão posiciona a produção de insetos comestíveis como uma parte crítica do movimento de ecoinovação, focando em seu potencial para reduzir o impacto ambiental. As evidências apontam que a criação de insetos, como grilos e larvas de *Tenebrio molitor*, consome significativamente menos recursos naturais, como terra e água, quando comparada à pecuária tradicional. Essa eficiência produtiva está relacionada, por exemplo, à menor taxa de conversão alimentar (FCR), na qual os grilos se mostram duas vezes mais eficientes do que frangos, quatro vezes mais do que suínos e doze vezes mais do que bovinos. Além disso, a eficiência proteica dos grilos (205g de proteína por kg de peso comestível) supera a das carnes convencionais.

Apesar do seu potencial, o estudo aponta as barreiras econômicas e estruturais significativas para aumentar a produção de insetos. Os altos custos associados à padronização, ao processamento em larga escala e à garantia da segurança alimentar ainda comprometem a viabilidade comercial, especialmente em mercados emergentes. Além disso, a ausência de regulamentações específicas em diversas regiões dificulta a consolidação do setor, restringindo o avanço da cadeia de valor dos insetos como uma alternativa consolidada para a alimentação humana e animal.

4.3 Resultados do Artigo 3

Artigo 3 - *Insect Production for Animal Feed: A Multiple Case Study in Brazil*

O estudo de caso de duas empresas no Brasil revela vários obstáculos específicos para a indústria local de produção de insetos, que incluem uma cadeia de suprimentos subdesenvolvida, falta de mão de obra qualificada e uma lacuna regulatória em relação ao uso de insetos na ração animal. Além disso, há ausência de uma rede colaborativa entre as empresas, que ainda operam de forma isolada, conduzindo todas as etapas do processo produtivo internamente. Esses desafios têm impedido as empresas de escalar sua produção e se tornarem competitivas em relação a fontes tradicionais de ração animal, como soja e farinha de peixe.

O estudo destaca que as larvas da mosca-soldado-negro apresentam uma oportunidade significativa para a produção sustentável de ração no Brasil. Essas larvas podem processar grandes quantidades de resíduos orgânicos, convertendo-os em ração rica em proteína para animais da pecuária, o que tem o duplo benefício de lidar com o desperdício de alimentos e criar uma fonte valiosa de proteína. Estudos citados no artigo apontam que essas larvas podem reduzir até 83,75% do volume de resíduos orgânicos e alcançar uma taxa de conversão de biomassa proteica de 23,2%. No entanto, os altos custos de produção e a falta de competitividade de mercado continuam sendo barreiras.

A análise das empresas Alpha Company e Beta Company fornece uma imagem clara de como diferentes empresas abordam o crescente mercado de insetos para ração. Enquanto a Alpha investe em parcerias com universidades e pequenos produtores, apostando na transferência de conhecimento e na expansão colaborativa da cadeia, a Beta aposta em tecnologia e integração vertical, realizando todas as etapas da cadeia de forma centralizada. Ambas utilizam a mosca-soldado-negro e estão em fase de desenvolvimento de plantas-piloto, com a ambição de liderar o mercado de ração alternativa na América Latina.

A análise SWOT revela que, embora o mercado tenha um potencial considerável, obstáculos regulatórios e altos custos impedem uma adoção mais ampla do mercado. Ainda assim, a abundância de resíduos orgânicos no Brasil oferece uma vantagem única para empresas que podem reduzir custos por meio do uso eficiente de materiais residuais na produção. O estudo conclui que, apesar da juventude do setor, há forte alinhamento com os Objetivos de Desenvolvimento Sustentável (ODS), em especial os ODS 2, 6, 12, 13 e 14, sinalizando que a cadeia de valor dos insetos pode se tornar um vetor estratégico para uma agricultura circular e sustentável no país.

4.4 Resultados do Artigo 4

Artigo 4 - *Key Performance Indicators (KPI) in the Edible Insect Value Chain: An Integrated Analysis from a Brazilian Perspective*

O artigo identifica os principais fatores que impulsionam o desempenho da cadeia de valor de insetos comestíveis no Brasil, destacando indicadores estratégicos que influenciam tanto a eficiência operacional quanto a competitividade de mercado. A partir da análise de produtores vinculados à ASBRACIA, emergiram cinco indicadores-chave que se mostram fortemente conectados entre si e com diferentes etapas do processo produtivo: qualidade do relacionamento com fornecedores, efetividade da segmentação de mercado, precisão na previsão de preços, vantagem competitiva no mercado e eficiência na transformação em produtos finais. Esses elementos funcionam como alavancas integradas, capazes de orientar decisões táticas e estratégicas para o fortalecimento do setor.

Esses cinco indicadores demonstraram elevada centralidade nas conexões da cadeia e influência direta sobre outras variáveis críticas. A qualidade das relações com fornecedores, por exemplo, está associada à estabilidade da produção, à redução de custos e à ampliação da base de clientes, evidenciando a importância de vínculos confiáveis ao longo da cadeia. A segmentação eficaz de mercado contribui para a expansão regional, a eficiência logística e a fidelização de consumidores, enquanto a capacidade de prever preços oferece maior precisão cenários de incerteza, permitindo ajustes ágeis na produção e nas finanças. A vantagem competitiva, por sua vez, está ligada à forma como as empresas se posicionam, diversificam canais e comunicam valor ao cliente. Por fim, a eficiência na transformação em produtos finais destacou-se como um indicador central das operações internas, com impacto direto sobre o processo de abate e separação das larvas, o aproveitamento de subprodutos e a capacitação da equipe.

O perfil dos produtores participantes reforça o caráter emergente da cadeia de insetos no Brasil: a maioria é de microempreendedores ou microempresas, com foco predominante em alimentação animal. As espécies mais utilizadas são *Hermetia illucens* e *Tenebrio molitor*, e os produtos são comercializados principalmente como insetos vivos, desidratados ou transformados em farinha. Apesar do avanço técnico em algumas unidades produtivas, o setor ainda enfrenta desafios estruturais, como baixa escala de produção, falta de regulamentação específica e limitações no acesso ao mercado formal.

O estudo também aponta que o fortalecimento da cadeia passa por ações coordenadas em diferentes frentes. No âmbito da gestão empresarial, o uso sistemático dos indicadores pode auxiliar empreendedores a identificar gargalos, priorizar investimentos e acompanhar a evolução dos processos. Na esfera política, os achados indicam a necessidade de regulamentações claras, incentivos à formalização e programas de apoio técnico que fortaleçam as capacidades locais, sobretudo em regiões rurais e periurbanas. Estratégias de *branding*, educação do consumidor e diversificação de canais também se mostram essenciais para aumentar a aceitação dos produtos à base de insetos no mercado brasileiro.

Em síntese, o artigo oferece uma contribuição relevante ao propor um modelo de avaliação baseado em indicadores de desempenho aplicáveis à realidade brasileira. Ao destacar os pontos de maior geração de valor e as conexões críticas da cadeia, a pesquisa fornece uma base prática para empreendedores e tomadores de decisão atuarem de forma mais eficaz em um setor promissor, alinhado aos princípios da bioeconomia, da circularidade e da segurança alimentar.

O Quadro 3 resume os principais resultados dos quatro artigos que compõem esta tese.

Quadro 3: Resumo dos principais resultados obtidos nos artigos

Artigos	Principais resultados
(1) Value Chain of Edible Insect Production: A Bibliometric Study Publicação: setembro/2022 DOI: 10.1007/978-3-031-16411-8_10	a) Aumento significativo no interesse global em pesquisas após 2015 b) Insetos têm propriedades científicas comprovadas que podem combater a desnutrição infantil e ser um excelente suplemento alimentar c) A cadeia de valor necessita de mais pesquisas para o desenvolvimento do processo de produção d) Falta de legislação para o consumo de insetos, apontada nos artigos científicos
Qualis A2 / Citescore Scopus: 2.4 (2) Eco-innovation and the Edible Insect Value Chain: A Systematic Review Publicação: março/2024 DOI: 10.5709/ce.1897-9254.524	a) Destaca a produção de insetos como parte fundamental do movimento de ecoinovação b) Demonstra que a criação de insetos reduz o uso de terra, água e recursos, em comparação à pecuária tradicional c) Novidade da pesquisa. Poucos artigos obtidos na revisão sistemática d) Quase metade dos investigadores interessados nos termos são do continente africano
Qualis A2 / Citescore Scopus: 5.8/ FI: 3,9 (3) Insect Production for Animal Feed: A Multiple Case Study in Brazil Publicação: julho/2023 DOI: 10.3390/su151411419	a) A produção brasileira enfrenta problemas como cadeias de suprimentos subdesenvolvidas, lacunas regulatórias e falta de mão de obra qualificada b) Barreiras impedem que empresas locais cresçam e concorram com fontes tradicionais c) As larvas de mosca-soldado-negro fornecem uma solução para converter resíduos orgânicos em ração rica em proteínas d) A análise SWOT revela pontos fortes na disponibilidade de resíduos orgânicos para alimentação de insetos no Brasil, mas suas fraquezas incluem barreiras regulatórias e necessidade de mais estudos
Qualis / Citescore Scopus: 5.5 (4) Key Performance Indicators (KPI) in the Edible Insect Value Chain: An Integrated Analysis from a Brazilian Perspective Status: em envio para a revista	a) Cinco indicadores se destacaram: relação com fornecedores, segmentação de mercado, previsão de preços, vantagem competitiva e eficiência na transformação em produtos finais b) Os indicadores apresentam forte interdependência, influenciando simultaneamente aspectos operacionais e mercadológicos. c) A cadeia é composta por micro e pequenas empresas, com baixa escala produtiva e desafios regulatórios. d) O uso integrado dos indicadores pode orientar decisões gerenciais e políticas para consolidar o setor como alternativa sustentável de proteína.

Fonte: Elaborado pela autora (2024).

4.5 Integração entre os principais resultados para a tese

No que tange à sustentabilidade, os quatro artigos enfatizam o potencial da produção de insetos comestíveis para reduzir impactos ambientais e fomentar uma economia circular por meio do aproveitamento de resíduos orgânicos. A eficiência na conversão de insumos, o baixo uso de recursos naturais e a valorização de subprodutos posicionam essa cadeia como uma alternativa sustentável às fontes convencionais de proteína.

Em relação às barreiras econômicas e regulatórias, os estudos, tanto em nível global quanto nacional, destacam os altos custos de produção, a baixa escala operacional e a ausência de marcos regulatórios como obstáculos significativos à expansão do setor. Esses desafios afetam diretamente a competitividade frente às proteínas tradicionais, dificultando a inserção ampla no mercado.

No que se refere ao potencial de mercado e crescimento, os artigos convergem ao apontar um cenário promissor, impulsionado pela maior conscientização sobre sustentabilidade e segurança alimentar. No entanto, ampliar a escala produtiva e garantir suporte regulatório contínuo são condições essenciais para viabilizar esse crescimento a longo prazo.

Os quatro artigos enfatizam o papel dos insetos comestíveis como uma alternativa sustentável às fontes tradicionais de proteína. O estudo bibliométrico sobre insetos comestíveis (Artigo 1) destaca o crescente interesse global em insetos como uma fonte de proteína mais ecologicamente correta. Da mesma forma, a revisão sistemática (Artigo 2) posiciona a cadeia de valor de insetos comestíveis como uma ecoinovação promissora que pode reduzir impactos ambientais, como emissões de gases de efeito estufa e consumo de recursos. O estudo de caso no Brasil (Artigo 3) examina ainda mais como a produção de insetos se alinha com as metas de sustentabilidade, utilizando práticas de redução de desperdício e eficiência de recursos, particularmente na produção de ração animal.

Já o estudo quantitativo (Artigo 4), por sua vez, evidencia que a eficiência na transformação de insumos em produtos finais e o aproveitamento de subprodutos são indicadores críticos de desempenho para viabilizar uma produção circular e de baixo impacto ambiental. Além disso, o artigo identifica conexões entre esses indicadores e práticas de capacitação técnica, diversidade de equipe e gestão de resíduos, mostrando que o capital humano e a inovação operacional também são fatores estratégicos para a sustentabilidade da cadeia.

Essas evidências reforçam a compreensão dos insetos como elementos centrais em sistemas verdes e sustentáveis. O Artigo 2 destaca sua elevada eficiência na conversão alimentar e a capacidade de utilizar subprodutos orgânicos como substrato, fortalecendo o argumento de que se trata de uma ecoinovação. Esse ponto dialoga com o Artigo 1, que aponta o crescimento global nas publicações científicas sobre o tema, refletindo um aumento no interesse por soluções sustentáveis para a produção de proteínas.

Um tema recorrente nos artigos são os desafios regulatórios enfrentados pela indústria de insetos comestíveis. O estudo bibliométrico (Artigo 1) e a revisão de ecoinovação (Artigo 2) destacam a falta de estruturas regulatórias em muitos países, o que dificulta a comercialização e a escalabilidade de produtos à base de insetos. O Artigo 4 reforça esse diagnóstico, mostrando que a falta de regras claras compromete a expansão comercial e a integração com mercados regulados, especialmente no setor de alimentação humana, evidenciando que a ausência de marcos legais impacta diretamente indicadores como segmentação de mercado e vantagem competitiva, dificultando o posicionamento estratégico das empresas.

Outro aspecto destacado é a questão da viabilidade econômica. Tanto a revisão de ecoinovação (Artigo 2) quanto o estudo de caso brasileiro (Artigo 3) abordam os altos custos de produção e a dificuldade em atingir competitividade de preços com fontes de proteína convencionais. Os estudos concordam que, apesar dos benefícios de sustentabilidade, os produtos à base de insetos atualmente enfrentam barreiras econômicas que devem ser abordadas por meio de inovação tecnológica, aumento da escala de produção e incentivos governamentais. O Artigo 3 acrescenta que os altos custos são particularmente problemáticos no contexto da cadeia de ração animal, onde as rações à base de insetos ainda não são competitivas em relação a fontes de proteínas convencionais. O Artigo 4 contribui com a proposição de indicadores voltados à análise da eficiência produtiva e da relação custo-benefício, trazendo subsídios para estratégias de gestão mais sustentáveis e orientadas ao desempenho. A análise estatística mostra que variáveis operacionais se correlacionam fortemente com o desempenho geral das empresas, oferecendo caminhos concretos para reduzir custos e aumentar a viabilidade econômica.

As diferentes escalas de análise também enriquecem a discussão. Enquanto os Artigos 1 e 2 mostram uma visão global sobre a temática, incluindo dados da Europa, da Ásia e da África, o estudo de caso (Artigo 3) oferece uma abordagem regional, evidenciando os desafios locais enfrentados pelas empresas brasileiras, como cadeias de suprimentos pouco estruturadas e escassez de mão de obra qualificada. O Artigo 4 complementa essa perspectiva ao apresentar um retrato quantitativo da realidade brasileira, mostrando que, apesar das limitações estruturais, há indicadores com forte potencial estratégico que podem ser utilizados para orientar decisões de crescimento e profissionalização da cadeia. Apesar das especificidades regionais, todos os estudos convergem quanto ao potencial dos insetos comestíveis em promover segurança alimentar e impulsionar o desenvolvimento socioeconômico.

A análise SWOT apresentada no Artigo 3 oferece uma visão estratégica ao identificar forças, fraquezas, oportunidades e ameaças da cadeia produtiva no Brasil. Essa abordagem complementa os demais estudos ao revelar que o país possui vantagens competitivas, como a abundância de resíduos orgânicos que podem ser utilizados como substrato, fator que contribui para a redução de custos. Por sua vez, o Artigo 2 aponta oportunidades associadas ao crescimento do mercado sustentável, enquanto o Artigo 1 alerta para ameaças, como o lento avanço regulatório e as barreiras econômicas. O Artigo 4, ao identificar a centralidade de variáveis como relacionamento com fornecedores e previsão de preços, contribui para uma visão mais tática das oportunidades de ganho de eficiência e posicionamento no mercado.

No que se refere ao potencial de mercado, os quatro estudos convergem. O Artigo 1 evidencia o fortalecimento do campo científico e o crescente reconhecimento da importância do tema. O Artigo 2 apresenta projeções positivas de crescimento, especialmente na América Latina, ressaltando o papel dos insetos como solução nutricional em contextos de insegurança alimentar. O Artigo 3 explora aplicações viáveis da mosca-soldado-negro na ração animal e em fertilizantes, com destaque para oportunidades na agroindústria. O Artigo 4 complementa, ao demonstrar, com base em indicadores como segmentação de mercado, previsão de preços e vantagem competitiva, caminhos estratégicos para acessar nichos especializados e expandir a cadeia em mercados convencionais.

5. CONSIDERAÇÕES FINAIS

De forma geral, os quatro artigos oferecem uma visão integrada e abrangente do estágio atual da cadeia de valor dos insetos comestíveis. A partir de abordagens complementares: bibliometria, revisão sistemática, estudo de caso e análise estatística, a pesquisa evidencia o alinhamento da cadeia com os princípios da ecoinovação, da bioeconomia e da sustentabilidade produtiva. No entanto, também revela a existência de desafios estruturais que ainda precisam ser superados, como a ausência de políticas públicas específicas, incentivos econômicos, padronização regulatória e estratégias empresariais mais coordenadas. O potencial identificado nos primeiros estudos é reforçado pela proposta de indicadores de desempenho apresentada no quarto artigo, voltados a dimensões críticas como transformação eficiente, vantagem competitiva e previsibilidade de preços. Esses indicadores fornecem subsídios concretos para o desenvolvimento de sistemas de monitoramento orientados por dados, apoiando a tomada de decisão por parte das empresas e promovendo o avanço estruturado do setor rumo à competitividade, eficiência e consolidação como fonte proteica sustentável em escala global.

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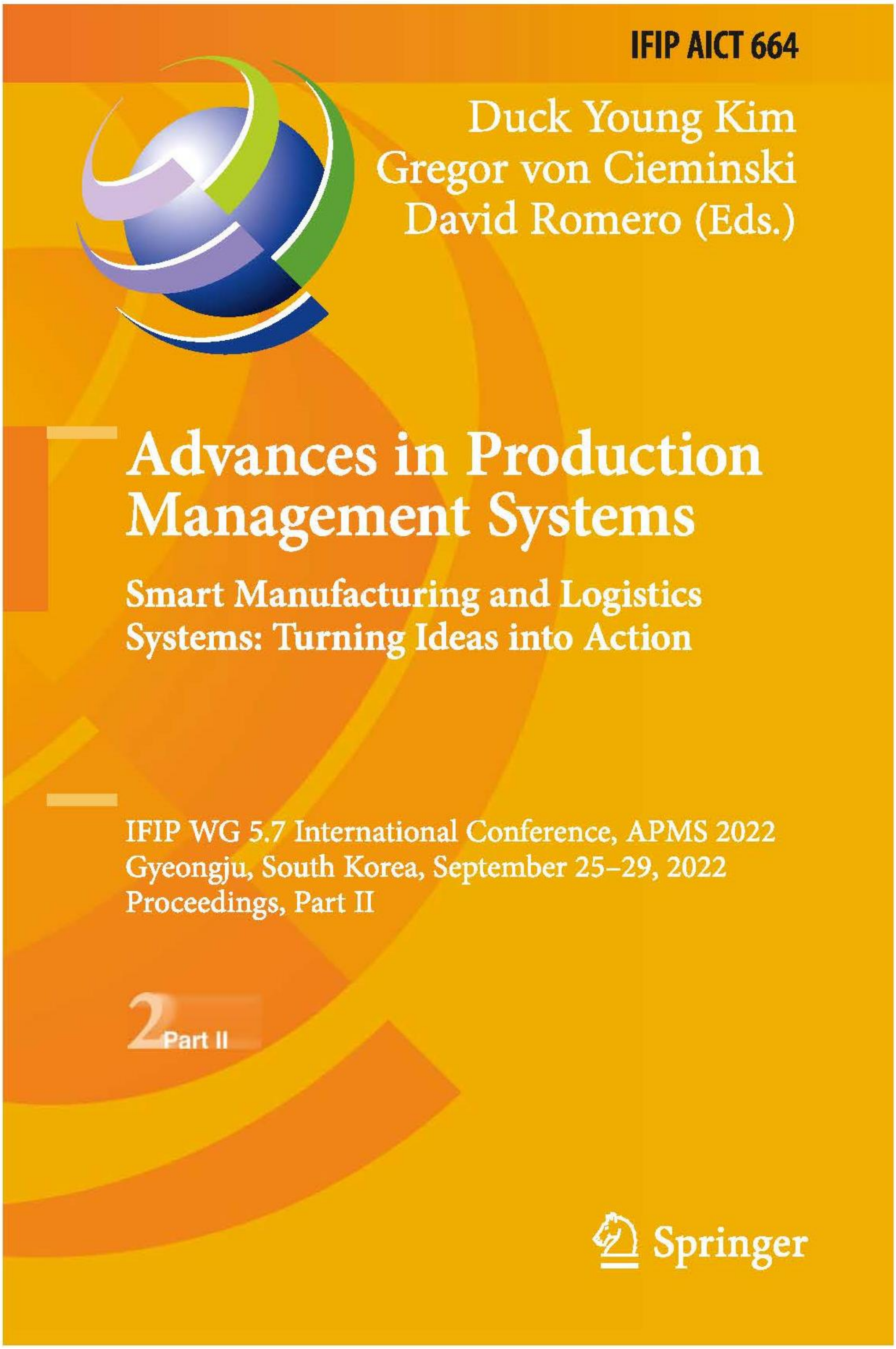
APÊNDICE A – Artigo 1



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Value Chain of Edible Insect Production: A Bibliometric Study

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Abstract. Projections by the Food and Agriculture Organization of the United Nations (FAO) of a significant increase in protein production by 2050 to feed an estimated 9 billion people raise concerns about healthiness and sustainability, as this growth is linked to the challenges non-increase in land use, decrease in energy and water consumption and reduction of CO_2 emissions. This scenario makes the food and food ingredients industry look for innovative ways of producing proteins. The production of edible insects is part of this quest. The objective of this article is to analyze the evolution of the scientific field of the role of insects in human food in a sustainable way, considering the state-of-the-art study (reference to the current state of knowledge about a particular topic being study) as a tool to analyze the value chain of edible insects. The bibliometric results show the evolution of publications referring to the term "edible insects", which were qualitatively categorized into three main topics: 15 articles about insects as food and feed, 34 articles about food science, and 1 article about veterinary humanities and social sciences. This article may be useful for researchers interested in the topic, especially those who wish to respond to the challenges imposed to meet the global demand for sustainable protein.

Keywords: Edible insects · Insect cultivation · Sustainability · Value chain

1 Introduction

According to updated projections from the Food and Agriculture Organization of the United Nations (FAO), a 60% increase in protein production will be needed by 2050 to feed a world population that will reach around 9 billion people [1]. A major challenge to meet this demand is related to how to do it without increasing the use of resources such as land, consuming less energy and water, and reducing CO 2 emissions. To meet this challenge, FAO points out the need to use alternative sources of proteins. An alternative to keep up with the increase in this demand is the production of edible insects as a sustainable proposal for human consumption [2].

Published by Springer Nature Switzerland AG 2022
D. Y. Kim et al. (Eds.): APMS 2022, IFIP AICT 664, pp. 74–82, 2022.
https://doi.org/10.1007/978-3-031-16411-8_10

Despite the worldwide attention on the topic, a bibliometric review on the Web of Science on the term "edible insects" resulted in only 50 articles, demonstrating a research gap. The objective of this article is to analyze the evolution of scientific articles on the role of insects for human food in a sustainable way. In this article the study of art will be considered to analyze the value chain of edible insect production.

2 Literature Review

2.1 Climate and Environmental Changes and the Cultivation of Insects

Global warming has become a problem, mainly due to the great impact it has on agriculture and consequently on food security, triggering climatic events that have affected food sustainability [3]. In this way, it has become a focus of interest for researchers from different areas, who strive to solve its negative and often irreversible effects [4].

As adaptation and mitigation strategies to combat the effects of climate change in 2015, 195 countries and the European Union (EU) signed the first universal global climate agreement, pledging to stop the rise in the planet's temperature below 2 °C above pre-industrial levels, significantly reducing the impacts of climate change.

According to Huis and Oonincx [5] to reduce such impacts, some measures can be taken, such as reducing demand for livestock products, reducing manure emissions, and increasing carbon sequestration in pastures. As a quarter of all anthropogenic greenhouse gas emissions from global food production, insect consumption has been suggested as a sustainable and healthier route to animal protein consumption [6].

Climate and environmental changes have contributed to the increasing popularity of this consumption. Thus, it has become increasingly important to protect traditional practices of harvesting edible insects, especially in countries where the practice is already a daily habit, as in several parts of Africa, and thus guarantee the availability of these resources for future generations [7].

2.2 Food Safety and Consumption of Edible Insects

According to the Committee on World Security, food security exists when all people always have access to sufficient food to meet their needs, considering four pillars: availability, access, use and stability, in which the nutritional dimension is considered a part. Integral to food security [8].

Simion et al. [4] consider the risks are global and access to food has become a challenge not only for developing countries, but an economic priority around the world, as many causes have contributed to the increase in food insecurity, such as: increasing population growth, global warming, use of food resources, natural disasters, and armed conflict. According to FAO data (2018), 60% of people who suffer from hunger are in countries affected by conflict and 40% are in countries that suffer from drought.

According to Van Huis [2], edible insects can contribute to food security and be the solution to the lack of nutrients, especially as a source of protein. In addition, the production of edible insects emits low greenhouse gas emissions, requires reduced land, and has high conversion efficiency, and insects can partially replace ingredients in compound feed for livestock and aquaculture, allowing cereals used as animal feed will be used for human consumption.

Countries such as Belgium, Switzerland and the Netherlands have shown favorability for the production and consumption of insects. Switzerland has supported the sale of crickets, locusts, and mealworms since 2015, while Belgium in 2014 concluded that it seems highly unlikely that insects raised in controlled and hygienic circumstances will become infected, although the heating step is essential before being infected. Available for consumption [8].

2.3 Edible Insect Value Chain

The topic of edible insects involves several areas of research, such as: nature conservation, food, feed, organic waste recycling, poverty reduction, business development, food and agricultural policy and legislation, involving many stakeholders who meet at different operational levels of the value chain [9].

Research on the consumption of edible insects has grown over the last few years, bringing together international scientists to present their analyzes and findings related to the applicability of consumption as a new source of protein, both for human food and for animal feed, in addition to considering the different stages of the value chain. An example of this scientific interest and commitment was the symposium held in 2018 in the Netherlands, which marked 10 years of research in this area [10].

Odongo et al. [11] investigated the commercialization of edible insects in Uganda and Burandi, describing the value chain and market opportunities, revealing results in which the edible insect trade presents an alternative source of livelihood from collectors, street vendors and traders alike of rural and urban areas. Research data showed that a specific kilo of edible insect cost US$3.00, while beef and fish cost US$3.50 and US$1.95 respectively.

Considering that insect value chains can suffer structural differences according to the analyzed country, Mermúdez-Serrano [12] elaborated a value chain of edible insects, considering an overview of the main actors involved, showing in Fig. 1.

The value chain of edible insects is composed of the main actors involved in production, processing, and international marketing, but does not consider the interrelationships between the different actors, since these relationships depend on the context in which they are inserted [12].

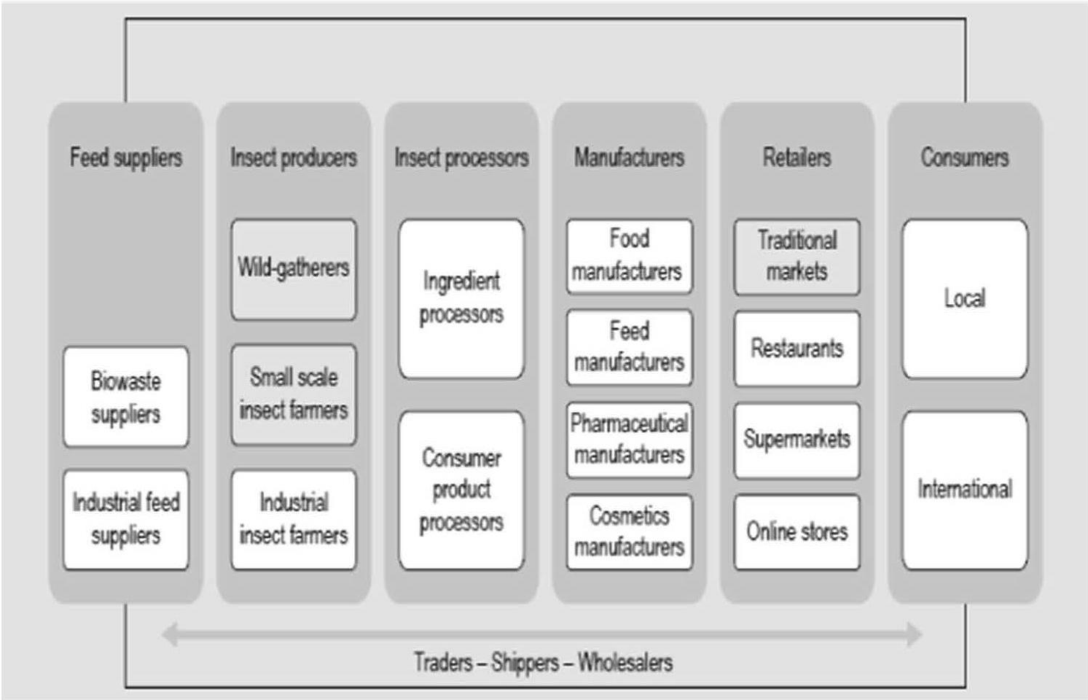

Fig. 1. Main actors in the edible insects' value chain

2.4 Regulation of Edible Insects

Since November 25, 2015, the EU, through Regulation 2015/2283, considers insects as a novel food, subjecting them to a simpler, clearer, and more efficient authorization procedure, in which insect-based foods can be marketed in throughout the territory, explicitly clarifying that insects can be consumed whole or in parts [12, 13].

However, this type of regulation does not occur in most countries, in which the lack of regulation is caused. Decision makers interpret insects as pests and not as potential food, directly affecting entrepreneurs as the challenges in marketing and product development increase, in addition to generating irrational exploitation, ineffective collections, promotion of monopolies, over-intermediation and poor conservation of the animals. Resources [12, 14].

According to Vantomme [9], FAO can help member countries by gathering and comprehensively disseminating the following information on edible insects, showing in Table 1.

Table 1. FAO - information on edible insects

Topics	Information
Nutritional composition	Nutritional composition tables for more insect species, promoting similar methodologies across countries on nutritional compositions of insect consumption, easily comparable with other major protein sources such as fish, chicken, pork, beans and pulses
Bioavailability of micronutrients	Such as iron, zinc and others, mainly due to the massive occurrence of these deficiencies in the tropics, leading to stunted growth in children. This is very important in many developing countries characterized by protein-deficient diets and where, for example, mixing cassava flour with ground insect powder could easily improve local diets.
insect processing	Extracts in recomposed foods: extraction of proteins and by-products such as fats, chitin, minerals, vitamins in hamburgers, spreads, energy bars, etc.
Legal and regulatory frameworks	Support inclusive legal and regulatory frameworks for insect consumption, such as novel foods, Codex Alimentarius, food safety standards, and healthy food regulations

3 Methodology

Considering the study of art to analyze the consumption of insects for human consumption in a sustainable way, the qualitative approach was adopted. This article was prepared through bibliographic research. Bibliometric analysis emerged with the aim of studying and evaluating scientific production activities in the early 19th century. Its development took place having as main landmark the studies from empirical laws on the behavior of literature [15].

The study used Thomson Reuters' Web of Science database, the former ISI Web of Knowledge, which is an online scientific information wizard. This database allows scholars access to journal articles, books, and other scholarly documents in all fields of science. In addition, Thomson Reuters Web of Science journals have impact factors in the Journal Citation Report (JCR).

To answer the research objective the search string "edible insects" was defined. After using the search string in the Web of Science database, the following criteria were used to select the articles included in this systematic review: Articles published in peer-reviewed journals or conferences that answer questions and research:

Articles published in the last 16 years, from 2006 to 2021;

- Studies available for download in the defined search bases.
- Duplicate studies were excluded from the sample.
- Articles that did not answer the research question were excluded.

Bibliometrics was carried out with the purpose of gathering knowledge about edible insects and other areas of knowledge, aiming to find primary studies on the subject and the solutions pointed out in the literature.

4 Analysis and Discussion of Results

The research examined articles published from 2006 to 2021 in the Web of Science database, focused on insect consumption, totaling a sample of 50 articles. The bibliometric indicators used considered: research publications on insect consumption; number of research papers on insect consumption published between 2006 and 2021; areas of knowledge in which the authors have published research on insect consumption and the authors published: insects as food and feed, food science and veterinary humanities, and social sciences. Food insects being the most studied topic with 34 articles. Bibliometric indicators are shown in Fig. 2.

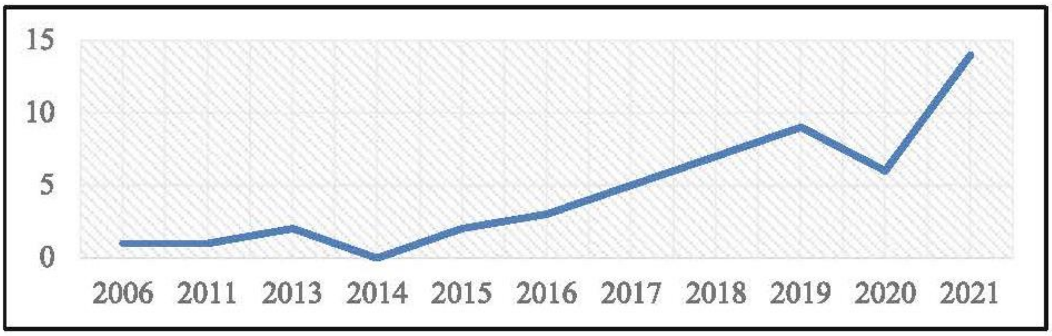

Fig. 2. Scientific production on insect consumption.

The period from 2006 to 2015 has an average of 1.5 articles per year. From 2016 to 2019, there was a linear growth of 2 articles per year, representing an annual average of 6 articles. After a decrease in 2020, it is possible to observe a significant increase in 2021 with the publication of 14 articles, demonstrating the evolution of research in the analyzed period. Based on the selected articles, the scientific journals were qualitatively categorized as follows: insects as food and feed, food science, and veterinary humanities and social sciences. The main contributions of the most recent publications are shown in Table 2.

Table 2. Categorization of selected surveys

Categorization	Authors	Main Contributions
Insects as food and feed	Mermúdez- Serrano (2020) [12]	It analyzes the potential for cultivation and processing of edible insects in Latin America, using the systemic competitiveness approach to list the main opportunities and challenges for the development of the sector in the region, considering the coordinated efforts between all the actors involved in the different systemic levels: entrepreneurs, research institutions, government, and society
	Niassy et al. (2018) [16]	Organization of the 22nd meeting of the Association of African Insect Scientists (AAIS) in Wad Medani, Sudan, in 2017, aiming to support impactful research that will produce genuine edible insect products, sustain value chains that improve food and nutrition security, and support sustainable livelihoods in Africa
	Vantomme (2015) [9]	Analyzes the main activities and achievements of insect recognition as a contribution to food security, suggesting ways forward, particularly from the FAO perspective
Food science	Ayieko et al. (2021) [17]	Selectively summarizes current trends related to the consumption of edible insects among residents, consumers in the food and beverage industry, and its prospects as a major draw in tourist destinations

(continued)

Table 2. (*continued*)

Categorization	Authors	Main Contributions
	Nyangena et al. (2021) [9]	Reviews the discussion of how climate change has affected food production and cash crops, along with animal production, the resulting human nutritional imbalances, and the impact of climate change on edible insects
	Kyung Kim et al. (2019) [18]	It summarizes current trends related to insects as food resources among consumers, industry, and academia, revealing that entomophagy is experiencing a steady increase worldwide, despite its unfamiliarity to consumers influenced by western eating habits
Veterinary humanities and social sciences	Musundire et al. (2021) [7]	It proposes a path that can accelerate the recognition and appreciation of edible insects as important food and feed resources in Sub-Saharan Africa, including improved policies to support good stewardship of these resources for sustainability

5 Conclusion

The objective of this article was to analyze the evolution of scientific articles and the role of insects for human food in a sustainable way. To achieve this objective, a bibliometric analysis was carried out in the Web of Science database. A list containing 50 articles published between 2006 and 2021 was diligently extracted and analyzed.

The bibliometric results of the term “edible insects” showed the evolution of publications. The period from 2006 to 2015 has an average of 1.5 articles per year. From 2016 to 2019, there was a linear growth of 2 articles per year, representing an annual average of 6 articles. After a decrease in 2020, it is possible to observe a significant increase in 2021 with the publication of 14 articles, demonstrating the evolution of research in the analyzed period. The content of scientific journals was qualitatively categorized into three main topics: insects as food and feed, food science, and veterinary humanities and social sciences.

From the analysis of scientific productions, it was possible to identify an increasing number of publications about edible insects, especially from 2017, strengthening the expansion of the field.

This article may be useful to researchers interested in the topic, especially those who wish to respond to the challenges imposed to meet the world demand for protein without increasing land use, consuming less energy and water, and reducing CO_2 emissions by 2050.

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APÊNDICE B – Artigo 2

Primary submission: 09.08.2013 | Final acceptance: 18.12.2023

Eco-innovation and the Edible Insect Value Chain: A Systematic Review

Jaqueline Geisa Cunha Gomes[1], Marcelo Tsuguio Okano[2], Samira Nascimento Antunes[1], Henry de Castro Lobo dos Santos[3], Edson Luiz Ursini[3], and Oduvaldo Vendrametto[1]

ABSTRACT

The growing interest in edible insects as a component in animal feed and human food has caught the attention of researchers from various fields, resulting in a multidisciplinary approach. This emerging value chain positions itself as a sustainable and innovative alternative when compared to traditional protein chains. In this scenario, the objective of this article is to conduct a systematic review to investigate and present research on the consumption of insects by humans and their use as animal feed in an eco-innovation context. Our investigations indicate that research on the value chain of edible insects is present on almost all continents, revealing a growing interest, especially in developing countries. In these regions, insect consumption not only addresses issues of food security but also contributes to income generation. The increase in research on alternative protein sources, such as edible insects, seems to align with a broader trend toward sustainability in food production, underscoring the relevance of the topic in the search for environmentally friendly solutions. Noteworthy results include global recognition and collaborative efforts in edible insect research, highlighting a collective approach to addressing challenges and exploring opportunities. This global cooperation underscores the significance of the topic and the necessity for innovative solutions in addressing environmental and food security challenges.

KEY WORDS: eco-innovation, edible insects, sustainability, human food, animal feed.

JEL Classification: Q0.

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1. Introduction

In the past, before the economic and industrial scenario we have now, humanity was forced to feed on various nutritional sources, including insects. However, the development of civilization led to the decline of the practice of entomophagy (Patel et al., 2019). This scenario, which is currently distant from society, may be just a few steps away from a major cultural, economic, and social change.

Research shows that entomophagy is practiced in one hundred and thirteen countries and that around two thousand, one hundred and eleven species of insects are consumed by two billion people, with the practice being most prevalent in tropical countries (FAO, 2013). According to Costa-Neto (2016) in Brazil, entomophagy is present in fourteen states, being practiced mainly by thirty-nine indigenous tribes. The creation of insects as a viable protein source represents a new concept for animal nutrition (Gomes et al., 2023).

The increasing population growth rate, food insecurity in some parts of the world, as well as the increasing demand for and increasing cost of ani-

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mal protein, will necessitate a significant increase in production and will place a significant burden on natural resources already limited by the population's growth (Lange & Nakamura, 2023).

There is a global food security alert, with the imminence of global food shortages if appropriate measures are not put into practice (Ayieko et al., 2021). This alert is supported by notes from the Food and Agriculture Organization of the United Nations (FAO) on the need for sustainable protein sources to feed a population estimated to reach nine billion by 2050 (United Nations [UN], 2015).

This need for sustainable protein sources has increased because current livestock production has contributed to several environmental problems such as deforestation, soil erosion, desertification, loss of plant biodiversity, and water pollution (Van Huis, 2015). In this way, the challenge of achieving food security has increased, as there are two challenges to be solved simultaneously: maintaining the quality of the food produced and the equitable distribution of this food (Wardhani and Haryanto, 2020).

Products from edible insects can contribute to the transition to markets for sustainable protein sources, as well as to food security (Veldkamp et al., 2022). In 2012, at FAO headquarters, a specialized consultancy jointly with the University of Wageningen and financial support from the Dutch government evaluated the potential of insects as human food and animal feed, allowing the exchange of information and knowledge to guarantee food security (Vantomme, 2015).

Insects have additional nutritional components and beneficial compounds, including lipids, vitamins and minerals, chitin, Phenolic compounds antimicrobial peptides, all of which contribute to a healthy state (Li et al., 2023). In addition to offering nutritional benefits and helping to combat hunger, edible insects can provide ecological and economic advantages, as they are a cheaper substitute for animal proteins (Patel et al., 2019).

In this way, the edible insect value chain can become a sustainable food system as it can guarantee food security through nutrients, in addition to guaranteeing the financial, social, and ecological pillars of sustainability in the long term (Kawabata et al., 2020).

There is already evidence of an understanding of wild insect populations due to climate change and the increase in the world population (Musundire et al., 2021). Therefore, the need to improve the commercialization of edible insects has become imperative, since a large part of the population, especially in developing countries, cannot access essential animal proteins (Agea et al., 2008; Von Braun, 2010).

The animal feed part of the value chain is also impacted by the growth of the world population, as the need for ingredients for feed for both livestock and pets also grows.

Regardless of the value chain, companies aiming to remain globally competitive need alignment in their activities. However, in practice, the strategy of international engagement and its success still lacks clarity for most business leaders, especially those operating in emerging economies and less developed countries (Vallina-Hernández et al., 2022). Other essential skills, such as agility and innovation, are also crucial for operating in complex environments that demand quick response capabilities and creative solutions to address emerging issues (Troilo, 2023).

Through the environmental problems arising from current livestock production (Van Huis, 2015), the challenges of feeding the world's population by 2050 (UN, 2015), and the global alert on food security (Ayieko et al., 2021), the research question that this work intends to answer is: can the value chain referring to the consumption of insects for human food and animal feed be considered an eco-innovation?

The purpose of this article is to investigate and present research on the consumption of insects by humans and as animal feed in an eco-innovation scenario. To achieve this objective, the research uses a systematic review.

Investigations indicate that research on the edible insect value chain is present on almost all continents. However, there is more emphasis on underdeveloped countries, which seek to combat hunger and improve income generation for their citizens through the consumption of insects.

It is important to highlight that the consumption of edible insects follows different paths depending on the country being analyzed. While in developed countries the consumption of insects, like any other type of consumption, is an individual choice that reflects eating habits, in poor countries, this consumption can contribute to combating hunger and generating income.

After this introduction, Section 2 discusses the literature review regarding the terms "value chain" and "edible insects". Section 3 describes the method for designing the survey. Section 4 analyzes and discusses the results of the systematic review, and Section 5 presents the conclusions.

2. Theoretical Framework

2.1. Eco-innovation and Edible Insects

Eco-innovation is the abbreviation of the term environmental innovation, whose objective is to reduce the negative influences of innovations on the natural environment (Reid & Miedzinski, 2008). The advantages of eco-innovation include a decreased environmental impact, increased efficiency, and enhanced competitiveness (Mady et al., 2023).

According to Kemp & Pearson (2007), the concept of eco-innovation is broad, including everything from pollution control to waste reduction. However, the relevant criterion for determining the term is whether the use is less harmful to the environment than the alternatives.

Eco-innovation can originate from new or improved solutions introduced throughout the lifecycle phase of the product or service, that is, from beginning to end. However, according to evidence, the greatest gains in resource efficiency are found in base production or in the intermediate part, while resource efficiency decreases along the supply chain (Reid & Miedzinski, 2008).

Because of the increasing significance of environmental concerns, depleting ecological resources, and increased environmental impacts, the study of eco-innovation is increasing in importance every day (Riaz et al., 2023).

The definitions of the term can have a motivational or result focus, according to the authors presented in Table 1 .

According to Table 1, the definition of eco-innovation is divided into two bases: environmental motivation (innovator's intention) and environmental results (effect on the environment), with environmental motivation being more difficult to verify than a focus on results (Carrillo-Hermosilla et al., 2010).

The value chain referring to the consumption of insects by humans and as animal feed is based on environmental results, considering the concept of Kemp and Pearson (2007):

Eco-innovation is the production, assimilation or exploitation of a product, production process, service or management or business method that is new to the organization (developing or adopting it) and which results, throughout its life cycle, in in reducing environmental risk, pollution and other negative impacts of resource use (including energy use) compared to alternatives.

Table 1

Focus of the Definitions of the Term Eco-innovation, According to the Authors

Authors	Focus	Scope
Rennings (2000)	motivation	sustainable development
European Commission (2008)	result	sustainable development
Andersen (2006)	result	reduction/prevention of environmental impact
Carrillo-Hermosilla, Río and Könnölä (2010)	result	reduction/prevention of environmental impact
Kemp and Pearson (2007)	result	reduction/prevention of environmental impact
	N	22

Source: Adapted from Koeller et al. (2019)

Table 2
Classification of the Term Eco-innovation

Classification	Description	Types
environmental technologies	pollution control technologies, including wastewater treatment technologies	waste management equipment; environmental monitoring and instrumentation; green energy technologies; water supply; noise and vibration control.
organizational innovation for the environment	introduction of organizational methods and management systems	pollution prevention schemes; environmental management and auditing systems; cooperation between companies to close material loops and avoid environmental damage throughout the value chain.
product and service innovation offering environmental benefits	new or environmentally improved products and environmentally beneficial services	new or environmentally improved material products (goods); green finance products: green leases or climate mortgages; environmental services: solid and hazardous waste management, water management; less polluting and resource-intensive services.
green system innovations	alternative production and consumption systems that are more environmentally benign than existing systems	organic farming; energy system based on renewable energies.

Source: Adapted from Kemp and Pearson (2007)

Furthermore, a new process that is more resource efficient or anything that is more benign to the environment than the previous alternative is considered an eco-innovation (Kemp & Pearson 2007).

Following this vision, Kemp and Pearson (2007) developed a classification for the term, according to Table 2.

According to the classification in Table 2, the value chain referring to the consumption of insects by humans and as animal feed fits into the typology of the classification of green system innovations. This environmental innovation suggests that there are higher chances of reaping positive social benefits resulting from this deeper commitment to long-term sustainable practices (Berrone et al., 2013).

Considering those viable insects for human consumption, such as mealworms, crickets, and grasshoppers emit fewer Greenhouse Gases (GHG) per kilogram of mass gain, when compared to pork and beef cattle (FAO, 2013), Reduced GHG (carbon dioxide and other gases) can contribute to the enactment of legislation aimed at decreasing the amount of these emissions, thereby lowering carbon footprint and alleviating concerns for consumers and shareholders.

The production efficiency of crickets is better than that of chicken and pork and beef cattle, as shown in Table 3.

According to Table 3, the Feed Conversion Ratios (FCRs)—a measure of an animal's efficiency to convert feed mass into increased body mass—of crickets are two times more efficient than those of chickens, four times more efficient than those of pork, and twelve times more than those of cattle. In addition, the protein efficiency of adult crickets is also higher compared to that of conventional meat, as shown in Table 4.

Table 3
Edible Insect Industry Segmentation

Segmentation	Analysis
products	beetles caterpillars grasshoppers, locusts, and crickets bees, wasps, and ants scale insects and true bugs other edible insects
application	flour bars snacks
regional	North America: U. S Europe: Belgium, France, UK, Netherlands Asia Pacific: China, Thailand, Vietnam Latin America: Brazil, Mexico Middle East and Africa

Source: GMI (2016)

According to Table 4, the protein efficiency of adult crickets is 205g of protein per kg of edible weight, while poultry, pork, and cattle present values of 200, 150, and 190 g of protein per kg of weight, respectively (Van Huis, 2013).

A probable explanation for the FCR of crickets being more efficient than that of meat from conventional animals is the fact that insects are poikilothermic, and in their growth stages there is no investment in metabolic energy to maintain a constant body temperature above environmental temperatures (Van Huis, 2013).

According to the mentioned data, edible insects can be sustainable protein sources, compared to other alternative sources (chicken, pork, and beef cattle), since they present greater production efficiencies and protein efficiency in terms of resources. Another factor contributing to the consumption of edible insects is studies that indicate that insect-based protein powder is less harmful to the environment than conventional proteins (Smetana et al., 2016).

Table 4
Production Efficiencies of Conventional Meat and Crickets

	cricket	poultry	pork	beef
feed conversion ratio (kilogram feed: kilogram liveweight)	1.7	2.5	5	10
edible portion (%)	80	55	55	40
feed (kilogram: kilogram edible weight)	2.1	4.5	9.1	25
efficiencies (kilogram edible weight) meat / efficiencies (kilogram edible weight) cricket		2	4	12

Source: Adapted from Van Huis (2013)

Furthermore, the need for sustainable protein sources has increased, as current livestock production has contributed to several environmental problems, such as deforestation, soil erosion, desertification, loss of plant biodiversity, and water pollution (Van Huis, 2015). Another positive comparative issue regarding livestock production and the production of edible insects is that insects can be cultivated using low-value organic products and byproducts. In this way, at the end of processing, it is possible to have high-value protein from agricultural products wasted daily (Van Huis and Dunkel, 2017).

2.2. Value Chain of Edible Insects for Human Consumption

Research shows that entomophagy is practiced in 113 countries and that about 2,111 species of insects are consumed by 2 billion people, with the practice being more prevalent in tropical countries (FAO, 2013). According to Costa Neto (2016) in Brazil, entomophagy is present in 14 states, being practiced mainly by 39 indigenous tribes.

Edible insects are a new form of food that has several benefits that will address the issue of protein and energy deficiency caused by the rapid growth of the world's population. Using insects as food can increase the economy and have a positive impact on the environment and human survival (Papastavropoulou et al., 2023).

According to Vantomme (2015), the consumption of insects can evolve in different ways in different countries, as it depends on the food culture, social values, local conditions, and livestock development needs. Another point that can drive this evolution is comparative studies of the nutritional value of edible insects with other conventional proteins (Patel et al., 2019).

The food security of villages and families in developing countries can be improved the more the preservation techniques are improved, reducing waste as well as the spoilage of harvested insects, allowing expansion for use in local diets, for example, the mixture of cassava flour with insect powder (Vantomme, 2015).

In Africa, researchers have been dedicated to understanding the value chain of edible insects. According to Niassy et al. (2018), research studies still lack the necessary details to allow strong industrial production on a commercial scale, an essential requirement for the advancement of marketing opportunities related to the production and consumption of insects.

The difference in this evolution can be seen in most sub-Saharan African countries, whose governments still do not recognize the contribution that entomophagy can offer as a guarantee of food security and informal income, mainly for women, children, and marginalized communities, whose income comes significantly from the insect value chain. Thus, strategies are needed to promote awareness of the value of insects, whether as human food, feed, or pharmaceutical options (Musundire et al., 2021).

However, the food safety achievable through entomophagy requires studies, as conducted by Mumbula et al. (2022). In their research on edible termites in Zambia, the collected samples showed microbial loads of Enterobacteriaceae, E. coli, S. aureus, yeasts, and molds. The analyzed termites might have been exposed to contamination during collection, transportation, or sale. Therefore, technological advancements are necessary to ensure the safety of edible insect consumption.

Although insects for human consumption are widely found in Africa, the formal industry in Europe and the USA is growing rapidly (Ayieko et al., 2021). In the East, the Korean market has been growing since 2012, through government support and successful research results (Kim, T-K et al., 2019).

In Europe, some companies already specialize in the production of insects for human consumption. In this way, these companies already follow protocols, such as hygiene, identification of product batches, and tracking. However, due to the low production volume, the costs are still high (Van Huis and Dunkel, 2017).

Despite the specialization in insect production, further research is still needed to provide insights into dietary changes based on edible insects, such as Tenebrio Molitor (TM), as emphasized by Errico et al. (2022) in their study. The research analyzed all high-value products obtained through TM, along with safety aspects. The authors emphasize that despite the approval of TM usage by the European Commission in 2021, certain aspects directly impacting the production process, such as health effects, optimal production conditions, and by-product conversion capabilities, need to be thoroughly discussed and analyzed.

Aiming to improve the acceptance of insects, research has addressed the functional properties of their proteins to be consumed as food ingredients, their gelatinization, foaming, and emulsification capabilities, as well as their solubility in oil and water. The diversity of ways of using insects can improve the attractiveness of their consumption (Ayieko et al., 2021).

To improve the issue of palatability and reduce possible aversions to whole consumption, insects can be transformed into powder or flour, in addition to being mixed with other ingredients, enabling increased sales, and generating more profit for the value chain into which it is inserted, such as the food tourism chain (Ayieko et al., 2021).

There is a wide variety of groups of edible insects in the world, which fall into different groups, as shown in Figure 1.

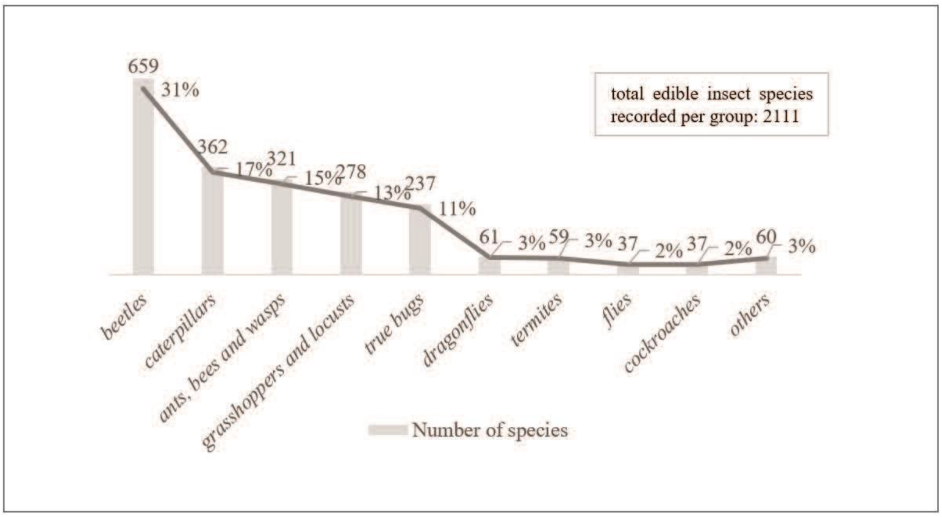
To be worth the effort of catching, insects need to be easy to locate and should preferably be collected in predictable and large numbers. They can be consumed at different stages of life and through different preparation methods: raw, fried, boiled,

Table 5
Protein Efficiencies of Conventional Meat and Crickets

	cricket	poultry	pork	beef
protein efficiency (kilogram protein: kilogram edible weight)	205	200	150	190

Source: Adapted from Van Huis (2013)

Figure 1
Number of Edible Insect Species Recorded per Group Worldwide



Source: Adapted from Jongema (2017)

roasted, and ground (Dobermann et al., 2017).

According to Kamau et al. (2021), crickets have a high potential in fulfilling the daily intake of several micronutrients. Research data carried out in Kenya demonstrate a collection of 0.5 to 3.0 kilograms of fresh weight in each harvest cycle (period of 45 to 60 days), corresponding to a daily intake of 100 grams of fresh crickets for a period from 5 to 30 days (consumed by at least one person per family). For this average daily intake, the protein contribution of crickets is in the order of 25% to 39% of the recommended daily protein for women, and 70% of the recommended daily protein for children.

Despite the continuing need for research to identify ideal foods, estimates for the world market for edible insects by 2023 are in the order of USD 522 million, with more than 40% CAGR (Compound Annual Growth Rate) from 2016 to 2023 (Kim, K-T et al., 2019; GMI, 2016).

GMI also analysed the edible insect industry and segmented it as per Table 3.

According to the analysis by GMI (2016), for Europe (specifically France, the United Kingdom, and the Netherlands) forecasts are that the edible insect market will show a high rate of expansion in the period from 2016 to 2023. For Latin America (mainly Brazil), projections are for a 42.4% CAGR and more than USD 55 million by 2023.

In this way, forecasts of growth of edible insects for human consumption present a great opportunity for new businesses, especially for developing countries (Dobermann et al., 2017). However, there is a challenge to be overcome. Scalability will only be viable once large volume production is possible (Van Huis and Dunkel, 2017).

Another important factor for the growth of the chain is the development of research such as that carried out by Odongo et al. (2018) on the commercialization of edible insects in Uganda and Burundi. They detailed the value chain and market opportunities, highlighting that the edible insect trade represents an alternative source of livelihood, ranging from collectors to street vendors and traders, in both rural and urban areas. The survey results revealed that the price of a kilogram of a specific edible insect was USD 3 compared to USD 3.5 for beef and USD 1.95 for fish.

Research such as that conducted by Donkor et al. (2022) supports the findings of Odongo et al. (2018) by confirming that the grasshopper value chain in Uganda is an excellent source of income for retailers. Among the research results, a notable aspect is the difference in average annual income between individuals working in the high season (around 8 weeks) within the grasshopper chain and those engaged in other sectors. The disparity in average annual incomes varies, with a 392% increase for women and a 451% increase for men involved in the grasshopper chain.

Furthermore, the retail sector in various countries is a crucial pillar for economies. For instance, in Puerto Rico, the sector employs over 20% of workers with an average wage of USD 8.69 per hour (Rios-Pérez et al., 2022). According to this data, the development of the edible insect value chain could strongly impact this sector.

2.3. Value Chain of Edible Insects for Animal Feed

The feed market is also impacted by the growth of the world's population, as the need for feed ingredients for both livestock and pets grow. Edible insects have garnered more scientific interest as a low-cost alternative to replace the need for soya bean and fish meal in animal feeds due to their nutritional value (Kolobe et al., 2023).

Since 2021, in Europe and Member States, processed animal proteins (PAPs) have been authorized for poultry and pork feed. This approval is one of the main stages of the authorization process and significantly marks the guarantee for the sustainable use of resources, both for the production and for the animal protein process, thus mitigating environmental concerns (Ankamah-Yeboah et al., 2018; Veldkamp et al., 2022).

In the West, there are several companies that breed insects for animal feed, such as fish, birds, and reptiles. However, the need for high-scale production and standard quality has been a bottleneck for these companies to achieve competitive production costs (Van Huis & Dunkel, 2017).

Currently in Europe, the aquatic feed market accounts for approximately half of all insect-based animal feed. Projections are for a 75% growth by 2030, as European insect breeders currently trade around 1000 tons of insect proteins (Veldkamp et al., 2022).

In addition to the potential commercial growth, research to evaluate different processing methods related to the digestibility of nutrients from this feed has also been growing. Processing methods impact the protein digestibility; so, finding the correct nutritional digestibility values has become a critical factor for formulating feeds, considering that there are variations in insect protein digestibility, according to each animal species fed (Veldkamp et al., 2022).

As a novel protein source, insects require the well-designed manufacturing process to produce high quality insect powder, while guaranteeing food safety of the final product (Yan et al., 2023).

According to Ankamah-Yeboah et al. (2018), there is a need for research to measure the impact of insect feed on the value of animal products, when used as a total or partial substitute for standard feeds, such as fish and soy meal. Currently, research is being carried out to analyze the effects of bioactive substances (component of a nutrient or non-nutrient food, which has a specific metabolic or physiological action in the human body) provided by insect meal as animal feed (Veldkamp et al., 2022).

However, various research studies addressing the process within the edible insect value chain encounter obstacles regarding knowledge sharing. As highlighted by Chiu et al. (2022), organizational knowledge is often accumulated over time, leading companies to be reluctant to share it without financial returns.

Considering the insect-based feed as a cheaper alternative to the standard feed and large-scale production, the manufacturers' profits can potentially increase if the cost reduction in feed inputs is considered. However, it is essential to understand consumers' reaction to this new production method, as well as their purchasing behavior (Ankamah-Yeboah et al., 2018).

Insects as a source of animal protein, especially in aquaculture, can influence the purchasing decisions of final consumers. Research carried out with 610 German consumers pointed out that only 23% of respondents care about the type of feed that the fish is fed. On the other hand, 77% of respondents are indifferent to the use of insect-based feed. These data bring promising perspectives for the market, since for the 23% who care about the feed, public and marketing campaigns can bring about changes in their preferences, inclining them towards a more positive attitude towards insect feed (Ankamah-Yeboah et al., 2018).

In addition to understanding the acceptability by final consumers, it is necessary to analyze other actors in the production chain, such as farmers who may use edible insects as feed. Studies conducted in Kenya on smallholder farmers' willingness to pay for insect-based feeds assessed farmers' knowledge of edible insect feeds and willingness to pay for the product.

According to Chia et al. (2020), the research results reveal that livestock producers are aware of the potential of insects as feed, allowing a positive attitude to the product and consequently encouraging producers to take risks in relation to the acquisition of the new product. Another important result concerns the willingness to pay for the new feed. Farmers are willing to pay more for insect feed for poultry, fish, and pork than for standard commercial feeds. This willingness increases, as knowledge about the new feed increases.

Data referring to the knowledge, attitudes, and practices of farmers in relation to insects as feed are shown in Table 6.

According to Chia et al. (2020), the production of insect-based feed opens new socioeconomic perspectives, especially for increasing job opportunities for young people and women along the entire value chain. The results demonstrate an opportunity for innovative and sustainable use of resources, as insect rearing minimizes the pressure on agricultural land use and marine resources. However, it is crucial to address findings such as those highlighted by Karmaker et al. (2023) in their research, indicating that sustainable practices are not prioritized by top management in small and medium-sized enterprises in volatile environments.

Beyond these points, the production of insects as animal feed requires strict monitoring regarding the concentration of heavy metals (cadmium and lead) in the substrates, aiming to guarantee the safety of the product, making it economically reasonable (Purschke et al., 2017). Most of the risks involved in processing insects for animal feed can be combated using technologies, especially in the processing part, through heat treatment, as heat destroys some of the harmful

Table 6

Farmers' Knowledge, Attitudes, and Practices Regarding Insects as Feed

Parameter	Description	poultry farmers (n = 409)	fish farmers (n = 241)	pork farmers (n = 307)
knowledge	aware that insects can be used as feed (%)	70	80	0
attitudes	insects are a good source of feed (%)	60	78	0
	make their own feed (%)	9	19	15
practices	ever used insects as feed (%)	31	34	0
	used commercial feeds (%)	80	72	68
	used conventional feeds (%)	78	68	84

Source: Adapted from Chia et al, (2020)

microorganisms (Guiné et al., 2020).

In addition to the market for human food and animal feed, insect production is already seen in other markets, such as cosmetics and traditional medicines. Businessmen in China have grown rich by breeding cockroaches for these markets specifically (Guiné et al., 2020).

Therefore, investments in technology that integrate the links and business processes involved in this value chain can contribute to companies reducing operational costs and improving operational efficiencies, with artificial intelligence algorithms as valuable allies (Haifeng et al., 2022).

3. Method

This article was developed through inductive reasoning using the systematic review method, that according to Sampaio and Mancini (2007) uses the literature on a given topic as a data source.

According to Kitchenham et al. (2008), the systematic review is characterized by the adoption of a methodology for identifying, analyzing, and interpreting all the evidence available during the research, so that it is free of bias and can be repeated if necessary. To allow readers to make their own analyses regarding the quality of the review methodology itself (Bearman et al., 2012).

The advantages of a systematic review include enabling a summary of studies on a given topic, allowing greater research results as their execution comes from primary sources (Sampaio and Mancini, 2007). The main objective is to summarize the evidence from primary sources, offering a comprehensive understanding of the researched topic, in addition to allowing a formal synthesis of the most relevant research results, since it is difficult to read all the articles (Bearman et al., 2012; Bie, 1996).

To address the research question on edible insects and value chain, the logical operator 'AND' was applied to combine the search terms 'edible insects' and 'value chain.' The chosen databases were Web of Science (WoS) and Scopus due to the quality and relevance of their publications. In the WoS database, the search was conducted in the 'theme' field, while in the Scopus database, it encompassed the 'title,' 'abstract,' and 'keywords' fields.

The database search adhered to specific criteria, including language, publication date, and the exclusion of duplicate studies. According to Crowther et al., (2010), it is important that at the beginning of the research, inclusion and exclusion criteria are established to obtain records with less bias and the possibility of quick revaluation in case of questions about the criteria used. These criteria include language, publication date, and duplicate data, also limiting studies by language may be acceptable, but in some areas, it may result in the loss of important data.

By filtering with the strings 'edible insects' and 'value chain,' the oldest article identified was dated 2015, and the most recent one was from 2022, marking the start year of this research. The filters yielded twenty-six non-duplicated articles across different languages and countries, offering a global perspective on the consumption of insects as food.

The data were processed in a spreadsheet, and the analysis began by reviewing the articles in descending order of citations, prioritizing the reading of those that highlighted crucial parts of the value chain in their abstracts, such as feed suppliers, insect producers and processing, manufacturers, retailers, and consumers. The results and discussions were developed based on these analyses, contributing to a comprehensive understanding of the value chain of insects as human food and animal feed.

Figure 2 presents the selection and evaluation process of the studies found.

4. Discussion and Results

Despite the worldwide attention to the need for sustainable protein sources and the multidisciplinary research on the theme "edible insects value chain", the terms "edible insects" and "value chain" resulted in only 26 articles in the Web of Science and Scopus databases, as shown in Appendix A.

A small number of articles were found, and the concatenated terms of the searches were recent. Thus, all the articles found were analyzed.

Bibliometric indicators from the research were obtained, such as the number of research publications, the number of publications by research areas, the number of citations of articles by research areas, journal productivity, and author productivity by continent and country.

Regarding the number of research publications, these data show the novelty of the subject, mainly considering that no filter of initial and final dates was considered at the time of the research.

In Figure 3, it is possible to analyze the number of research publications on edible insects and value chain during the period from 2015 to 2022.

According to Figure 3, the period from 2015 to 2018 presented an average of 2.5 articles per year. In 2019, there was a decrease in the number of articles, with a slight linear increase observed in the following years at a constant rate of two articles per year. The average annual rate after 2019 is four articles. It is important to note that the research was concluded before the end of 2022. Thus, the number of articles for the year may be higher.

The data reveals a consistent growth trend in recent years, indicating a steady rise in the production of articles related to the subject. The highest annual average underscores ongoing and potentially increasing interest in the study area, despite the temporary decrease in 2019.

The notable novelty of the topic suggests that research on the value chain of edible insects as an alternative protein source is an emerging area of study, indicating a growing and potential demand for information.

The increase in research may reflect an awareness of the importance of sustainable approaches in food production, as consumers and the industry are increasingly interested in food options that minimize environmental impact. These findings align with Van Huis's (2015) research, indicating that alternative protein sources like edible insects are more sustainable compared to livestock production, which contributes to various environmental issues.

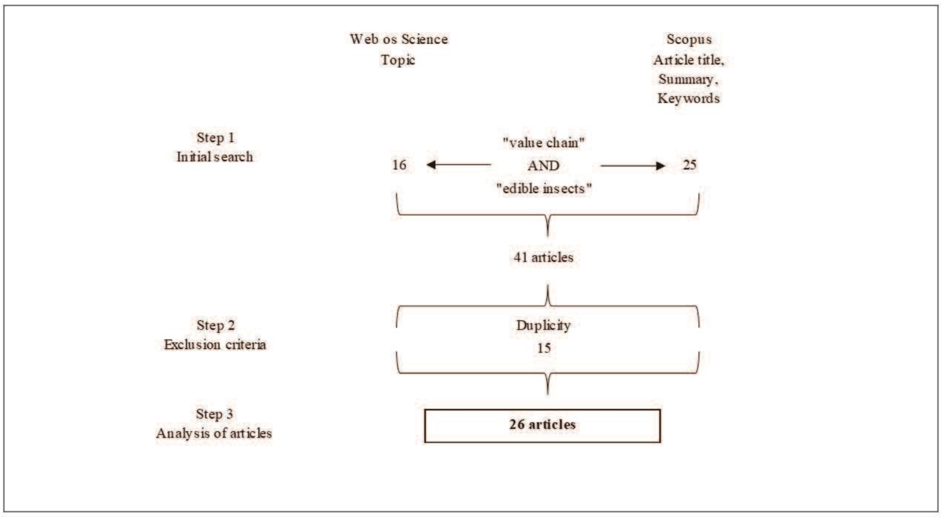
In summary, the growth in research on alternative protein sources, such as edible insects, appears to align with a broader shift toward sustainability in food production, highlighting the significance of the topic in the quest for more environmentally friendly solutions.

Regarding the number of publications by research areas, it was possible to identify the research areas for the terms "edible insects" and "value chain," allowing for a comprehensive mapping of the production system in which the value chain of edible insects is situated. Figure 4 illustrates the number of publications by area of research on edible insects and value chain.

To determine the research areas of the journals, the Journal Citation Reports (JCR) categorization was utilized. Journals with more than three categorizations were designated as multidisciplinary, while those not listed in the Journal Citation Reports were disregarded. Figure 4 highlights the main areas of interest in research on edible insects and the value chain.

The first category, representing 35% of the articles, was published in journals categorized as entomology and food science and technology. The second category, with 19% of publications, covers food

Figure 2
Selection and Evaluation Process of the Identified Studies



science and technology, followed by the multidisciplinary category, comprising 15% of publications. These data indicate that researchers have a significant focus on the relationship between technology and food science.

Technology plays a crucial role in various productive systems, driving innovations in production to increase efficiency, reduce waste, and optimize resources. In agriculture, intelligent monitoring has enhanced the quality and safety of food. Additionally, the analysis of large volumes of data over time enables the prediction of future scenarios, especially in response to environmental impacts.

According to Kemp and Pearson (2007), technology also has the power to accelerate developing production chains. This is how the use of technology has contributed to the advancement of the edible insect chain, especially in terms of food safety. Research worldwide is conducted to ensure that this new protein source is safe for both animal feed and human consumption.

Another crucial aspect is the application of information technologies in consumer education, especially regarding new foods. Communication and education can be facilitated through social media and digital platforms, providing consumers with a deeper understanding of the quality, safety, and processing of new products, promoting transparency in this new chain.

The intersection of technology and food science results in significant advances for the edible insect chain, especially concerning environmental issues, bringing benefits to society.

Through the number of citations of articles by research areas, it is possible to identify the most relevant ones for reading and further exploration in future research. Figure 5 presents the number of article citations by research area in the journals.

For duplicate articles, the highest number of citations among the databases was considered. Journals not listed in the Journal Citation Reports were disregarded. Thus, according to Figure 5, the most cited articles were found in three main categories: entomology/food science and technology, with 296 citations; multidisciplinary, with 234 citations; and food science and technology, with 174 citations.

These three main categories represented more than 60% of the total citations, aligning with the analysis of data derived from the number of publications in the research areas on edible insects and the value chain. Notably, there was an alternation between food science and technology and multidis-

Figure 3
Number of Research Publications Between 2015 and 2022

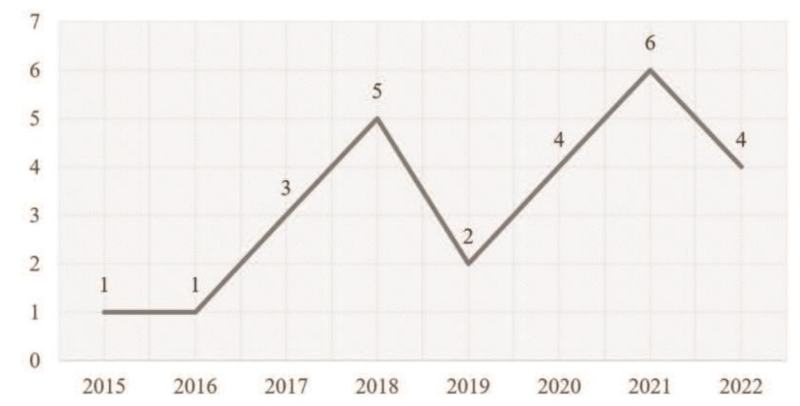
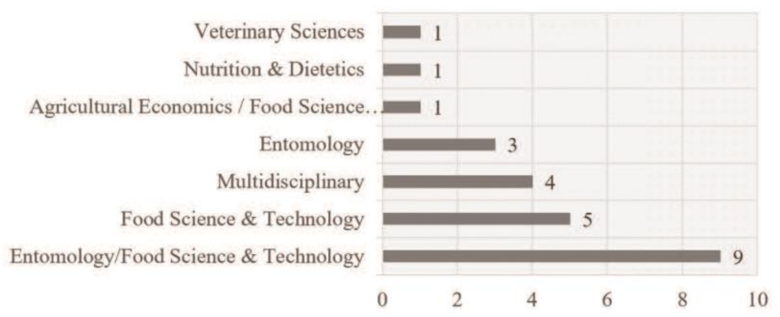


Figure 4
Research Areas on Edible Insects and Value Chain



ciplinary in the second and third positions.

While entomology provides knowledge about the biology, physiology, and ecology of insects as a potential food source, food science and technology offer analyses of nutritional properties, food safety, and processing of potential edible insects. Both areas converge to drive innovation in the edible insect value chain.

The development of a productive chain requires the involvement of various disciplines. Multidisciplinary collaboration is crucial to mitigate challenges and explore the potential of edible insects. As highlighted by Van Huis and Dunkel (2017), in addressing edible insects for human consumption, indicating the need to expand the chain to achieve substantial volumes, improve palatability to increase acceptance, and analyze the functional properties of insect proteins as food ingredients. This is due to the diversity of ways insects can be used, enhancing their attractiveness for consumption (Ayieko et al., 2021).

In the context of edible insects for animal feed, advances in science and technology enable more efficient pathogen detection, identification of ideal insect types for each species to be fed, and optimal proportions of adding insect protein to feeds.

The productivity of journals also needs to be analyzed. Knowing the journals that publish the most on the researched topic allows a better selection of articles for understanding the terms, as well as facilitating the literature review in a way that familiarizes the research focus of each journal.

Table 7 presents the 16 journals found and their respective productivity.

According to Table 6, the journal with the highest productivity is the Journal of Insects as Food and Feed with nine articles found; followed by Frontiers in Sustainable Food Systems and International Journal of Tropical Insect Science, each with two articles. These three journals together represent 50% of the total productivity, with the remaining productivity spread among the other journals.

Table 7
Productivity of Journals

Journal Information	Publications	Percentage
Journal of Insects as Food and Feed	9	35%
Frontiers in Sustainable Food Systems	2	8%
International Journal of Tropical Insect Science	2	8%
British Food Journal	1	4%
Comprehensive Reviews in Food Science and Food Safety	1	4%
Edible Insects in Sustainable Food Systems	1	4%
Food Additives and Contaminants Part A-Chemistry Analysis Control Exposure & Risk Assessment	1	4%
Food and Energy Security	1	4%
Food Quality and Preference	1	4%
Frontiers in Veterinary Science	1	4%
Insects	1	4%
Journal of Ethnobiology and Ethnomedicine	1	4%
NFS Journal	1	4%
Nutrition Bulletin	1	4%
PlosOne	1	4%
Waste Management	1	4%
Total	26	100%

The analysis of this information highlights the thematic specialization of each journal in approaching research on edible insects. Articles found in the Journal of Insects as Food and Feed focus on entomophagy in Africa, especially in informal contexts. This reflects specific attention to the region and local practices, indicating a commitment to understanding the cultural and social nuances associated with insect consumption.

The journal seems to concentrate not only on dietary aspects but also on broader implications such as food and nutritional security. The exploration of parts of the production process, such as fermentation, suggests an interest in understanding not only insect ingestion but also their preparation and processing as food. Furthermore, by addressing market opportunities, the journal recognizes the economic importance of this practice in the food chain, both for human and animal consumption.

The journals Frontiers in Sustainable Food Systems and International Journal of Tropical Insect Science have articles about insect farming by refugees in Africa. This focus highlights the practical and potentially transformative application of entomophagy in specific contexts where food security may be a central concern. By investigating the nutritional quality and safety of insects, these journals contribute to a more holistic understanding of the benefits and challenges associated with using insects in food.

Moreover, the exploration of current trends related to insect consumption in human food and gastronomy by these journals indicates a connection to broader debates on food sustainability and contemporary dietary choices. This suggests that these journals are attentive not only to technical and scientific aspects but also to evolving cultural and social dynamics related to insect consumption.

Overall, this diversity of approaches among the journals highlights the complexity and breadth of the emerging field of research on edible insects, encompassing specific regional issues to global considerations of sustainability and food security.

Another important indicator refers to the author productivity by continent and county. Know the origin of the publications makes it possible to identify countries interested in the researched theme, as well as to be aware of the universities in which the research is concentrated.

Figure 6 shows the countries of the authors of each article from the survey.

The analysis of the data reveals that 49% of the authors are from the African continent, with 13 of these authors being of Kenyan nationality. In second place are authors of European nationality, representing 43% of the total, with four of German and Danish origin, and three of Belgian and Dutch origin, as shown in Figure 6. These data provide insights into the countries and territories most engaged in research on edible insects and their value chain.

The presence of authors from different continents and international collaboration in various articles suggests that research on edible insects is a globally recognized area of interest. The diversity of collaborations transcends borders, indicating a collective approach to addressing challenges and exploring opportunities related to edible insects.

This data reflects significant interest in the topic, especially among researchers from developing countries. These researchers aim to tackle challenges such as hunger and improve income generation by promoting the consumption of insects. The connection between research on edible insects and food security in developing countries is evident, suggesting that these countries see insects as a potential solution to food challenges.

As an example, there is insect farming in Cambodia, which is used to mitigate rural poverty, increasing the income of family farming through the production of crickets (Guiné et al., 2020). The results obtained also reflect how this value chain is analyzed with interest by African countries, concerned about the food security of their population (Kawabata et al., 2020).

The diversity of nationalities among the authors may also reflect different cultural perspectives on insect consumption. This cultural diversity can influence research approaches, considering factors such as dietary preferences, social acceptance, and culinary traditions. The results suggest that research in this area may have positive impacts globally, but particularly in vulnerable communities.

An important point to highlight is the divergence

Figure 5
Number of Citations of Articles by Research Areas

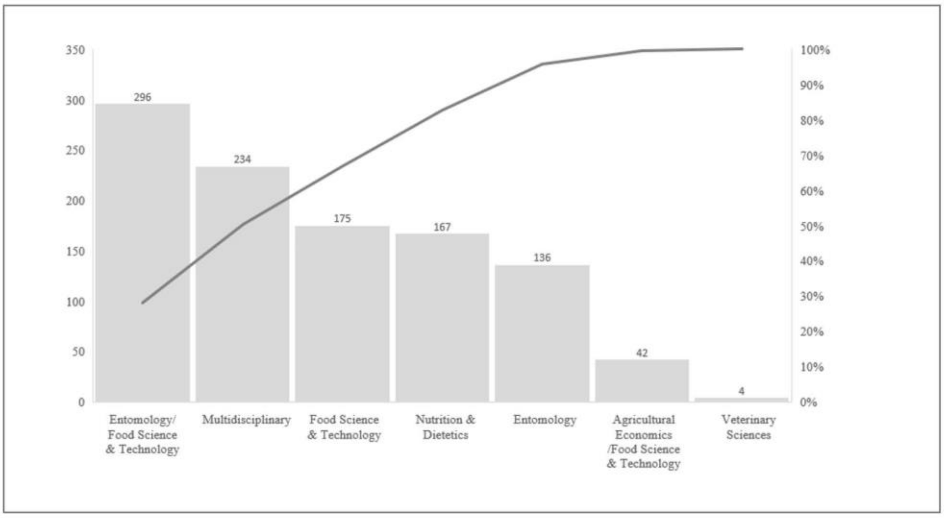
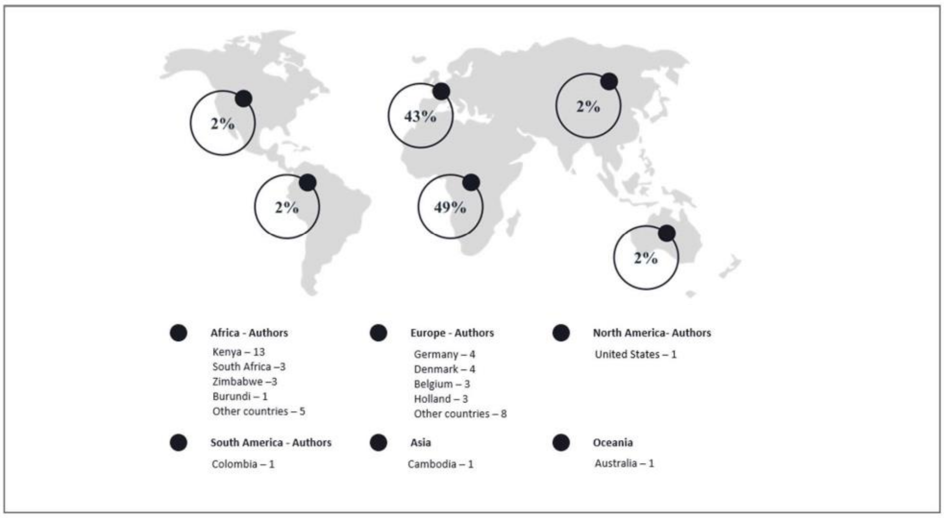


Figure 6
Author Productivity by Continent and Country



in the paths of edible insect consumption, depending on the country under analysis. This divergence between developed and developing countries is a complex phenomenon that reflects both cultural differences and distinct socio-economic contexts.

In developed countries, the consumption of insects is more aligned with an individual choice, often linked to dietary, environmental, or even gastronomic considerations. It is an expression of personal food preferences, and in some cases, it can be seen to explore new protein sources or adopt more sustainable diets. In these contexts, the acceptance or rejection of insect consumption is often associated with individuals' willingness to try new foods and overcome cultural barriers related to food taboos.

In developing countries, on the other hand, the consumption of insects plays a more vital role, contributing to addressing significant challenges such as hunger and income generation. In many communities in these countries, insects represent a valuable source of essential nutrients, offering an affordable and readily available alternative to address nutritional deficiencies. Additionally, the breeding and commercialization of insects can become important economic activities, providing livelihoods for local communities.

This differentiation highlights the importance of understanding the consumption of edible insects not only as a global trend but as a practice deeply rooted in specific contexts. Research and policies related to edible insects should consider these nuances to develop effective approaches that promote food security and sustainability, considering the distinct characteristics of each cultural and economic scenario.

5. Conclusion

The objective of this research to investigate and present research on the production of insects for human consumption and animal feed in an eco-innovation scenario was achieved.

The value chain referring to the consumption of insects for human food and animal feed is an eco-innovation, because the production process proves to be more efficient in terms of resources than the production process of pork, chicken, and beef cattle, as highlighted in previous studies that analyze the conventional meat production compared to that of crickets, that demonstrated that the feed conversion rate of crickets is twice more efficient than that of chicken, four times more efficient than that of pork, and twelve times more than that of cattle.

In terms of the focus of the definitions of the term eco-innovation, the value chain referring to the consumption of insects for human food and animal feed, focuses on environmental results, whose scope is the reduction/prevention of environmental impact, since its innovative intends to mitigate environmental problems arising from current livestock production, aiming to respond to global alerts on food security regarding the need for sustainable protein sources for the future.

Edible insects are an alternative system of production and consumption that is more environmentally benign than the existing systems related to the production of chicken, pork, and beef cattle, as indicated in previous research, which indicated that insects viable for human consumption, such as mealworms, crickets, and grasshoppers, emit fewer Greenhouse Gases (GHG) per kilogram of mass gain when compared to pork and beef cattle.

Other results obtained also compared four different types of animals, in which the protein efficiency of adult crickets is 205g of protein per kg of edible weight, while poultry, pork, and cattle present values of 200, 150, and 190 g of protein per kg of weight, framing the value chain referring to the consumption of insects by humans and as animal feed in the classification typology of green system innovations.

The notable novelty of the topic suggests that research on the value chain of edible insects as an alternative protein source is an emerging area of study, indicating a growing and potential demand for information. The growth in research on alternative protein sources, such as edible insects, appears to align with a broader shift toward sustainability in food production, highlighting the significance of the topic in the quest for more environmentally friendly solutions.

Another important result is the application of information technologies in consumer education, especially regarding new foods. Communication and education can be facilitated through social media and digital platforms, providing consumers with a deeper understanding of the quality, safety, and processing of new products, promoting transparency in this new chain.

The presence of authors from different continents and international collaboration in various articles suggests that research on edible insects is a globally recognized area of interest. The diversity of collaborations transcends borders, indicating a collective approach to addressing challenges and exploring opportunities related to edible insects.

In conducting this study, we chose to utilize the Web of Science (WOS) and Scopus databases for analyses. The specific selection of these databases may have led to the exclusion of relevant articles that could have further enriched the scope of the research. We acknowledge that information availability extends beyond these databases, and therefore, the inclusion of other sources is crucial for a comprehensive analysis.

An additional limitation lies in the incomplete exploration of other information sources, such as conference proceedings and books. The exploration of such material is vital, as these formats often capture innovative research and preliminary results that may not have been formally published in journals. This limitation underscores the importance of adopting a more inclusive approach in the pursuit of knowledge.

We also identified a significant opportunity for future research, focusing on the relationship between eco-innovation and specific sustainable development goals. This proposal is based on the growing need to understand how eco-innovation practices can contribute to specific goals, going beyond general analysis. By concentrating on key areas of sustainable development, research can provide more targeted and practical insights to guide policies and business practices.

Another possibility is to explore consumer perception and acceptance of products resulting from eco-innovation in the edible insect value chain. This would involve investigating factors influencing the acceptance or rejection of these products and examining how the message of sustainability and innovation can be communicated more effectively to consumers.

An additional propose would be test specific strategies to engage value chain stakeholders, including producers, consumers, and government regulatory agency. Involvement of these stakeholders can contribute to creating a more conducive environment for eco-innovation in this emerging chain.

Ultimately, we recognize that this study represents a specific contribution to an evolving field, and we suggest these directions for future research to further enhance understanding of the intersection between eco-innovation and the edible insect value chain.

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Appendix A

Table 1

Results of Systematic Review

Authors	Article Title
Egonyu, J.P; Kinyuru, J. Fombong, F. Ng'ang'a, J. Ahmed, Y.A. and Niassy, S.	Advances in insects for food and feed
Kelemu, S., Niassy, S., Torto, B., Fiaboe, K., Affognon, H., Tonnang, H., Maniania, N.K. and Ekesi, S.	African edible insects for food and feed: inventory, diversity, commonalities and contribution to food security
Münke-Svendsen C., Ao, V., Lach T., Chamnan C., Hjortsø C.N. and Roos N.	An explorative study of the practice of light trapping and the informal market for crickets in Cambodia
Imathiu, S.	Benefits and food safety concerns associated with consumption of edible insects
Alemu, M.H., Olsen, S.B., Vedel, S.E., Pambo, K.O. and Owino, V.O.	Combining product attributes with recommendation and shopping location attributes to assess consumer preferences for insect-based food products
Niassy, S., Musundire, R., Ekesi, S. and Van Huis, A.	Edible insect value chains in Africa
Alemu, M.H., Olsen, S.B., Vedel, S.E., Pambo, K.O. and Owino, V.O.	Edible Insects as New Food Frontier in the Hospitality Industry
Lakemond, C.M.M., Veldkamp., T. and Van Huis, A.	Edible insects: the value chain
Van Campenhout, L.	Fermentation technology applied in the insect value chain: making a win-win between microbes and insects
Ojha, S., Bussler, S. and Schluter, O.K.	Food waste valorisation and circular economy concepts in insect production and processing
Espitia Buitrago, P.A., Hernández L.M., Burkart, S., Palmer, N. and Cardoso Arango, J.A.	Forage-Fed Insects as Food and Feed Source: Opportunities and Constraints of Edible Insects in the Tropics
Donkor, E., Mbeche, R. and Mithofer, D.	Gender differentials in value addition and lean season market participation in the grasshopper value chain in Uganda
Purschke, B., Scheibelberger, R., Axmann, S., Adler, A. and Jager, H.	Impact of substrate contamination with mycotoxins, heavy metals and pesticides on the growth performance and composition of black soldier fly larvae (Hermetia illucens) for use in the feed and food value chain
Ankamah-Yeboah, I., Jacobsen, J.B. and Olsen, S.B.	Innovating out of the fishmeal trap: The role of insect-based fish feed in consumers' preferences for fish attributes
Kamau, E., Kibuku, P. and Kinyuru, J.	Introducing cricket farming as a food security and livelihood strategy in humanitarian settings: experience from Kakuma Refugee camp, Kenya
Niassy S., Ekesi S., Hendriks S.L. and Haller-Barker A.	Legislation for the use of insects as food and feed in the South African context
Odongo, W., Okia, C.A., Nalika, N., Nzabamwita, P.H., Ndimubandi, J. and Nyeko, P.	Marketing of edible insects in Lake Victoria basin: the case of Uganda and Burundi
Mumbula, I., Nyunja, R. and Chungu, D.	Microbial load of edible termites (macroterme spp.) from collection to marketing in Serenje District, Central Zambia

Table 1

Results of Systematic Review (Continued)

Authors	Article Title
Veldkamp, T., Nathan, M., Frank, A., David D., Van Campenhout, L., Gasco, L., Roos, N., Smetana, S., Fernandes, A. and Van der Fels-Klerx, H. J	Overcoming Technical and Market Barriers to Enable Sustainable Large-Scale Production and Consumption of Insect Proteins in Europe: A SUSIN-CHAIN Perspective
Meutchieye, F. and Niassy, S.	Preliminary observations on the commercialisation of Rynchophorus phoenicis larvae at Mvog-Mbi market in Yaoundé, Cameroon
Kinyuru, J.N and Ndung'u, N.W.	Promoting edible insects in Kenya: historical, present and future perspectives towards establishment of a sustainable value chain
Chia, S.Y., Macharia, J., Diiro, G.M., Kassie, M., Ekesi, S., Van Loon, J.J.A., Dicke, M. and Tanga, M.C.	Smallholder farmers' knowledge and willingness to pay for insect-based feeds in Kenya
Musundire, R., Ngonyama, D., Chemura, A., Ngadze, R.T., Jackson, J., Matanda, M.J., Tarakini, T., Langton, M. and Chiwona-Karltun, L.	Stewardship of Wild and Farmed Edible Insects as Food and Feed in Sub-Saharan Africa: A Perspective
Errico, S., Spagnoletta, A., Verardi, A., Moliterni, S., Dimatteo, S. and Sangiorgio P.	Tenebrio molitor as a source of interesting natural compounds, their recovery processes, biological effects, and safety aspects
Bomolo, O., Niassy, S., Tanga, M.C., Chocha, A., Tartibu, L., Shutcha, M.N., Longanza, B., Ekesi S. and Bugeme, D.M.	The value chain of the edible caterpillar Elaphrodes lactea Gaede (Lepidoptera: Notodontidae) in the Miombo forest of the Democratic Republic of the Congo

APÊNDICE C – Artigo 3

sustainability

MDPI

Article

Insect Production for Animal Feed: A Multiple Case Study in Brazil

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Abstract: The production of insects as a sustainable protein source represents an innovation for animal feed. The objective of this research is to analyze the value chain of the use of edible insects in animal feed in Brazil through the framework of SWOT, the business model sustainable canvas, and a multiple case study, highlighting the sustainability characteristics. A qualitative approach of the descriptive exploratory type was used, and the multiple case study identified the actors in the chain and how value is generated. The young age of the sector explains the characteristics observed in the Brazilian chain, such as a large development deficit in terms of financing, technology and the qualification of human resources; a disorganized supply chain and supplier structure; and efforts undertaken by regulatory agencies to promote the development of regulations relating to the production and use of insects in animal feed, which, in turn, will lead those wishing to participate in this innovative venture into research and development in the area. Brazil's edible insect supply chain can become a more significant aspect of sustainable agriculture by closing nutrient and energy loops, promoting food security and minimizing climate change and biodiversity losses, all of which are associated with the achievement of the Sustainable Development Goals.

Keywords: value chain; edible insects; insect cultivation; animal nutrition

Citation: Gomes, J.G.C.; Okano, M.T.; Ursini, E.L.; Santos, H.d.C.L.d. Insect Production for Animal Feed: A Multiple Case Study in Brazil. *Sustainability* **2023**, *15*, 11419. https://doi.org/10.3390/su151411419

Academic Editor: Dimitris Skalkos

Received: 28 June 2023
Revised: 19 July 2023
Accepted: 21 July 2023
Published: 23 July 2023

1. Introduction

The global demand for feed, as well as the competition for protein, grows annually. Research is carried out worldwide to mitigate possible protein production shortages, which will need to be increased by sixty percent by 2050 to meet future world demand [1]. Another aspect affecting the animal protein production system is the high inputs required to produce feed, the global demand for which will reach more than 1 billion tons by 2050 (an increase of 60 to 70% compared to around 800 million tons in 2018) [2].

One of the biggest challenges related to this future demand is increasing the availability and simultaneously reducing the use of natural resources, such as land for soybean planting and water, as well as reducing greenhouse gas emissions. The use of insects as a partial or total ingredient in animal feed has been shown to represent an alternative source of protein and a substitute for traditional feed.

Some research has demonstrated that the consumption of red meat is associated with an increased probability of stroke, diabetes, colon cancer and lung cancer. Insects seem to have a more nutritious and healthier composition than meat-based foods, and they are also diverse in terms of nutritional value. As a result, they can be used as meat substitutes [3,4]. These problems encourage a decrease in meat consumption and its replacement with insect consumption. This is valid not only because they offer replacement protein, but because of insects being a more sustainable, healthy and economical product.

Studies such as those performed by Chia et al. [5] show that animal protein producers are aware of the potential related to using insects as a feed ingredient, and that producers' knowledge is directly proportional to their willingness to pay for this new type of feed.

In the study "Insects as a sustainable feed ingredient in pig and poultry diets—a feasibility study" [6], the actors involved in the production chain of using insects as a sustainable ingredient of pork and poultry feeds are demonstrated, along with a discussion of how their integration can influence the implementation of insects as an alternative source.

This article aims to analyze the value chain of using edible insects in animal feed in Brazil through the framework of SWOT and a sustainable business model canvas and multiple case study, highlighting the sustainable characteristics. As this value chain is still in its nascent stages in Brazil, the following actors were not considered: the poultry/pork sector and retail/consumers.

2. State of the Art

The most promising insects for use in industrial feed production are the black soldier fly (BSF) (*Hermetica Illucens*), the housefly (*Musca domestica*) and the yellow mealworm (*Tenebrio molitor*) [6].

Zhou et al. [7] summarized the nutritional value of different classifications of edible insects. The composition of the nutritional value of edible insects is illustrated in Figure 1.

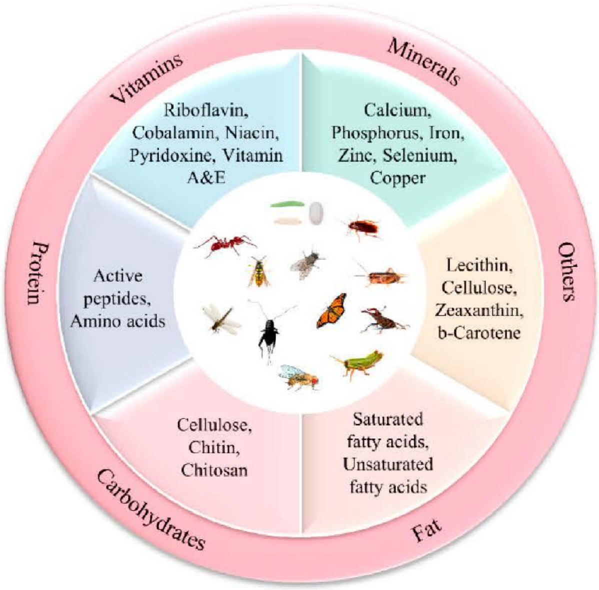

Figure 1. Nutrient composition of edible insects. Based on Zhou et al. [7].

The general composition of edible insects is listed in Figure 1. Different units are employed to represent the data due to the different sources from which they are derived, and the lack of their completeness is a result of the conversion units used. The material composition of insects is markedly different between species. In the dry matter, protein and fat are the most common substances [7].

Insects have tremendous potential at all life cycle stages as sources of nutritional value; they are a significant source of animal protein, contain essential amino acids and minerals (K, Na, Ca, Cu, Fe and Zn), and their fatty acids are unsaturated. The assimilation rate of insect proteins is 76–82%. Insect carbohydrates are primarily composed of chitin, which is present at a concentration range of 2.7 mg to 49.8 mg/kg of dry mass [8].

Table 1 presents Shah et al.'s [9] assessment of the types of economical insects and their chemical compositions and nutritive values.

Table 1. Types of economical insect and their chemical composition and nutritive value.

	Percentage (%)									Milligram per Kilogram (mg/kg)				
Insects Species	**DM**	**CP**	**CF**	**Ash**	**Ca**	**P**	**Mg**	**K**	**Na**	**S**	**Zn**	**Cu**	**Mn**	**Fe**
Black soldier fly larvae	27.40	56.10	23.20	9.85	2.14	1.15	0.39	1.35	0.13	27.04	13.10	11.20	23.20	20.40
Housefly larvae	83.47	33.29	6.20	6.25	0.49	1.09	0.23	1.27	0.54	ND	10.39	32.40	42.50	47.50
Mealworm larvae	94.60	55.83	25.19	4.84	0.21	1.06	0.30	1.12	0.21	ND	138.2	29.40	05.70	71.50

DM, dry matter; CP, crude protein; CF, crude fiber; Ash; Ca, calcium; P, phosphorous; Mg, magnesium; K, potassium; Na, sodium; S, sulfur; Zn, zinc; Cu, copper; Mn, manganese; Fe, iron. Source: Shah et al. [9].

The DM content in fresh BSFL (Table 1) is greater than that of other products (34.9 to 44.9%), which results in BSFL being more affordable and easier to make. Typically, BSFL has a composition of 41.1 to 43.6% CP, 15.0 to 34.8% EE, 7.0 to 10% CF, 14.6 to 28.4% ash, and 5278.49 kcal/kg GE, based on DM [10,11]. BSFL larvae are high in Ca (5 to 8%) and P (0.6 to 1.5%). Additionally, their mineral composition contains Cu (6.0 mg/kg), Fe (0.14–14%), Mn (246 mg/kg), Mg (0.39), Na (0.13), K (0.69%) and Zn (108 mg/kg) [9,12,13].

On average, housefly larvae contain 6.25% ash, 83% DM, 33.29% CP, 6.2% CF, 0.49% Ca, 1.09% P, 0.23% 1.27% Mg, 10.39 mg/kg Zn, 32.40 mg/kg Cu, 42.50 mg/kg Mn and 47.50 mg/kg Fe, based on DM (Table 1) [9]. Housefly larvae contain a lot of energy, protein and micronutrients (e.g., Cu, Fe and Zn), as well as EAA and FA. They are also inexpensive, have high nutritional value and are easier to access than other sources of animal protein [9].

According to Shah et al. [9], the average total DM composition of mealworms is 94.6%, comprising CP 55.83%, CF 25.19%, ash 4.84%, calcium 0.21%, phosphorous 1.06%, Mg 0.3%, K 1.12%, Na 0.21%, Zn 138.2 mg/kg, Cu 19.4 mg/kg, Mn 5.7 mg/kg and Fe 71.50 mg/kg (Table 1).

The edible insect sector has attracted global attention, and this has led to a re-assessment of the practice of entomophagy, or the consumption of insects, in countries that typically show reservations, as well as in countries that are entering the developmental stages of the practice [14].

In Europe, the aquatic insect feed market constitutes approximately half of the entire animal-based insect feed market. Its growth is expected to reach 75% in the next 6 years, and European breeders of insects currently carry around 1000 tons of protein-based insect feeds [15]. Since 2021, in the European Union and member states, processed animal proteins (PAPs) have been permitted for use in poultry and swine feed. This approval represents one of the first steps in the general authorization process, and will ultimately guarantee long-term resource utilization in animal protein production, thus addressing environmental concerns [15,16].

According to Lähteenmäki-Uutela et al. [16], in many parts of North America, insects have historically been incorporated into the food culture. The farming of insects intended for food and feed production began to increase following 2012. The modern insect industry comprises companies that already cultivate crickets and mealworms for animal food. To avoid the high costs of labor, many American and Canadian insect farms have invested in robots, automation, sensors and data aggregation.

Many countries in Africa have insufficient or no insect-specific laws, regulations, standards, or labeling in place to regulate the production and distribution of insects in food or feed chains. The absence of a solid foundation is a significant obstacle to the establishment of markets for insects and their related products [17]. There is a need for more enhanced technology in the rearing of insects to address the increasing pressures of population growth, as we can no longer rely on the catching of wild insects [17].

In several Asian countries, insects have historically been regarded as a form of food, and been used as a significant source of protein. In China, there are no specific laws that regulate their production. Other insects can also be utilized as food additives, and in this context, producers must follow the regulations established in the Administrative Measures for Food and Feed Additives [18]. In South Korea, insects have been a part of the human diet for centuries; they are also included in animal feeds, and there are no specific rules restricting the food and feed industry in relation to insects due to a legislative liberalization that took place in 2015 [19].

In Brazil, the food insect chain is still in its early stages of development, and there is still a significant lack of development in terms of funding, technology and the qualification of human resources. There have also been efforts made by regulatory agencies to promote the development of regulations pertaining to the production and utilization of insects in animal feeds, which will, in turn, encourage those who want to participate in this innovative endeavor [20].

Currently, in Europe, there is a supply–demand gap in the edible insect chain [15]. This scenario also applies to Brazil, as agrofactories still cannot access the necessary volumes (of consistent quality) required for processing insects, and the feeds produced are not competitive in terms of their costs compared to conventional protein sources. In the Brazilian scenario, logistical issues make the process more expensive, and hinder the growth of the chain. Furthermore, there is no knowledge on the part of protein producers about the effects of insects as a feed ingredient.

Another major challenge is that induvial companies are involved from the beginning to the end of the process. As such, they represent a significant part of the chain, from insect breeding to processing, thus raising production costs. As has been seen in Europe [15], it is expected that in the future, Brazilian companies will specialize as the value chain matures.

Shah et al. [9] have shown that a hypothetical expansion of commercial farms (that spend EUR 1000 per month on SBM-derived protein) would involve completely replacing SBM with BSF, HF or MW. The extra costs associated with these species are EUR 88,230, 3980 and 13,010, respectively. If we consider that the farmers farm every season, it would be extremely expensive for them to turn over the production of a whole field. In order for insects to be considered a viable alternative to SBM and FM, both cost and nutritional value must be maintained. For this to be successful, expenditure on insects must be reduced to EUR 0.4 per kilogram of direct weight based on 35% DM substances [9]. The economic values of different insects compared to other sources of protein are shown in Table 2.

A very important element of the end of the chain is the acceptance of insect-based feeds. The study carried out by Ankamah-Yeboah et al. [21] showed that 77% of the people interviewed are indifferent regarding the use of insects in animal feed for fish, which is a promising result for the aquaculture industry.

Not all insects can only be used as ingredients in animal feed. According to Čičková et al. [22], some insects can play dual roles within the chain, such as via the recycling of their organic by-products in compost fertilizers, and the use of their protein as feed. Another challenge encountered at the beginning of the chain relates to the food that insects can consume. These include residues, such as perishable organic by-products. These by-products are a valuable energy source for insects, but require producers to employ preservation techniques that both maintain the nutritional quality of the biomass and are economically viable [23].

In 2022, each person in Brazil generated an average of 1.043 kg of waste per day; that is, almost 1 kg per person. In general, 81.8 million tons of domestic waste were produced, which corresponds to 224 thousand tons per day (2022 edition of the *Panorama of Solid Waste in Brazil*, by ABRELPE) [24].

Table 2. The economic value of insects compared to other protein sources.

Potential Source	Housefly Maggot	Black Soldier Fly	Mealworm	Fishmeal	Soybean Meal
CP (%)	50.4	42.1	52.8	75.4	52.00
Lysine (%)	6.1	6.6	5.4	7.5	6.3
Methionine (%)	2.2	2.1	1.5	2.8	1.3
PPR (EUR/kg)	1.08	20	3.7	1.24	0.2
PP (EUR/kg)	2.14	47.51	7.01	1.64	0.54
PL (EUR/kg)	0.13	3.14	0.38	0.12	0.03
PM (EUR/kg)	0.05	1.00	0.11	0.05	0.01
PP TO PP SBM [1)]	3.98	88.23	13.01	3.05	1.00
PL TO PL SBM [1)]	3.85	92.23	11.15	3.64	1.00
PM TO PM SBM [1)]	6.73	142.52	15.02	6.58	1.00

CP, crude protein; PPR, product price; PP, protein price; PL, price of lysine; PM, price of methionine; PB, protix biosystems; AP, agriprotein. [1)] PP to PP SBM, price of replacing 1 kg of protein derived from SBM with other protein sources; PL to PL SBM, cost of replacing 1 kg of lysine derived from SBM with lysine from other protein sources; PM to PM SBM, cost of replacing 1 kg of methionine from SBM with methionine derived from other protein sources. Source: Shah et al. [9].

In Brazil, organic waste represents approximately 50% of all solid waste generated. Dry recyclables (28%) and waste (22%) are the next most prolific elements. The size of the organic fraction affirms the importance of using these residues in different ways, and avoiding their unnecessary disposal [25]. In addition, less than 2% of organic waste is currently composted in Brazil [25], and the storage of large batches of waste is a problem, since it cannot be immediately offered to insects [23].

Black soldier flies (BSFs) have received increased attention in recent years because of their capacity to contribute to sustainable waste management and renewable energy. In Brazil, the species that currently receives the most attention is the BSF. BSF larvae are voracious feeders and have the capacity to convert food waste into protein and lipid products [26]. Within the field of sustainability, BSFs are considered an interesting solution to reduce the ecological impacts of food waste. In transforming waste into valuable products, BSFs contribute to reducing the emission of environmental pollutants and greenhouse gases [26]. We highlight below some experiments carried out on BSFs and reported in published scientific articles and Master's theses.

Silva et al. [27] aimed to create a demonstration unit for black soldier fly larvae (*Hermetia illucens*) using organic waste from a restaurant located at the Federal University of South and Southeast Pará. It was known from previous experiments that the production of larvae of the black soldier fly can be used to efficiently decompose organic residues, transforming them into liquid composts and soils ready to be used in the cultivation of vegetables and the preparation of seedlings.

In Santos' Master's thesis [28], the objectives involved valuing the by-products of the food industry, obtaining a potential ingredient for animal feed, and also verifying the influence of diet on the weight, length and nutritional composition of BSF larvae. The results show that the diet significantly influenced the weight and average length of the larvae. Regarding the nutritional composition of the larvae, the protein content was not altered by the diet supplied, but the fat and ash contents of the diet directly influenced the composition of the larvae.

Teixeira Filho [29] proposed a possible solution to mitigate two issues: the disposal of solid organic waste and the pressure on the current supply of food protein. This solution is based on the mass production of larvae of *Hermetia illucens* (L., 1758) (Diptera: Stratiomyidae), also known as the black soldier fly, to degrade organic solid waste and also as an alternative source of animal protein. They achieved an 83.75% reduction in organic solid waste by employing a solid-waste-to-protein biomass conversion rate of 23.2%. This work provides a good indication that the mass production of the black soldier fly to enable the destruction of organic waste and for subsequent use as a source of animal protein is an excellent and sustainable alternative solution to problems related to solid waste and protein supply.

The treatment of organic waste is related to several SDGs, but specifically to numbers 2 (Zero Hunger and Sustainable Agriculture), 12 (Responsible Consumption and Production) and 13 (Action Against Global Climate Change).

Agricultural and food or agro-food supply chain (AFSC) encompasses all stages, from cultivation to harvesting, packaging, processing, transporting, marketing and distribution and final consumption. It not only entails general risks, including social, political, cultural and economic; due to the perishable nature of the products, seasonality, weather effects and quality and safety requirements, the chains are even more vulnerable [30–32]. The productive chain of edible insects operates like an agro-food chain, and to verify its characteristics, we will employ two frameworks.

All parts of the value chain of producing edible insects as an alternative protein source for animal feed, and the associated challenges, can be analyzed through the sustainable business model canvas, as shown in Figure 2.

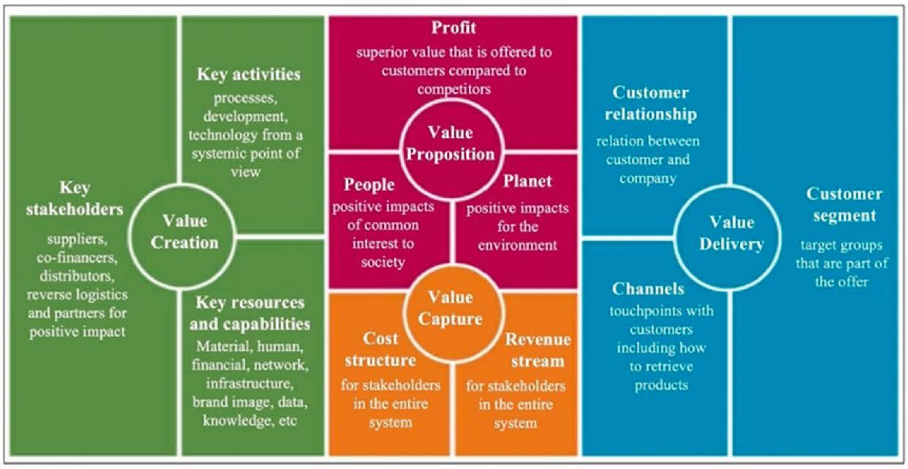

Figure 2. Screenshot of the sustainable business model canvas. Source: adapted with permission from Bocken et al. [33], Osterwalder and Pigneur [34] and Richardson [35].

Figure 2 depicts the business model canvas and introduces three new archetypes into the value proposition aspect: profit, people and planet. These make it a sustainable model with a holistic approach, the main (and most challenging) objective of which is to act sustainably in the future, with a simultaneous focus on environmental, economic and social changes [33].

The supply chain of edible insects will be evaluated using the SWOT matrix. SWOT is a helpful tool that can be used during the evaluation phase in order to yield a first interpretation of the possible future consequences. SWOT analysis is a simple method that provides a factual interpretation of the benefits and drawbacks of a business [36].

According to Benzaghta et al. [36], the SWOT matrix (Figure 3) can be summarized as follows:

- SO strategies—taking advantage of opportunities;
- ST strategies—avoiding threats;
- WO strategies—introducing new opportunities by reducing weaknesses;
- WT strategies—avoid threats by minimizing weaknesses.

Figure 3. Screenshot of the sustainable business model canvas. Source: Based on Benzaghta et al. [36].

3. Methodology

This qualitative research approach considers the current state of the art of using insects for animal feed, organic waste and other sustainable actives. To enact this evaluation, bibliographical research was carried out, using the search strings "value chain" and "edible insects" in the databases Web of Science and Scopus.

To meet the research objective, articles with information on the use of edible insects for animal feed and organic waste were selected. The intention was to present the current state of the art in this field of research and to broadly contextualize it, highlighting the value chain of this agri-food chain in Brazil by focusing on two companies that operate in the area. A descriptive exploratory case study was carried out, and through interviews it was possible to analyze the business models of two Brazilian companies active in the edible insect sector.

For confidentiality reasons, the companies are named Alpha and Beta. Their main characteristics are described below.

Alpha company was created in 2015 with the aim of contributing to the development of sustainable food, focusing on insects with high nutritional quality as a protein source. The company's mission is to work towards resolving the food issue by 2050. The company seeks to have a social and environmental impact, in addition to generating profit. The owner of the company first encountered edible insects in 2013, according to a report by the FAO and a later interview undertaken with the researcher, professor doctor Van Huis.

Beta company was created in 2022 with the aim of ensuring food safety and quality in producing animal feed. The company produces protein and oil through a circular process. The company began operations about three and a half years ago with a specific project, and it has positioned itself in the market as a company that combats hunger, is sustainable and combines financial prosperity with the protection of the environment.

The methodological procedure employed consists of the following steps:

1. Sources of evidence for the case study—As a source of internal evidence, interviews were conducted with the owners of Alpha and Beta companies. External evidence sources were not used, as the companies do not have websites containing relevant data for this research, and it was not possible to access internal documentation, such as meeting minutes, process reports or quantitative data.
2. Research instruments—A pilot interview was carried out with one of the companies to assess whether the theoretical concepts reflect the day-to-day activities of the company. The pilot interview aimed to delineate the actors in the chain, including those related to biowaste, the rearing of insects, the processing of insects, the feed sector, the protein sector and retail/consumer. Subsequently, the final interview script was prepared based on the sustainable business model (Figure 1) [33–35];
3. Data collection—Interviews were conducted using a semi-structured script and the business owners were interviewed. These were scheduled and performed remotely, and were recorded and transcribed. Each interview was approached as a detailed case study of the parts of the respective business;
4. Data results—The collected data were compared with the theoretical assumptions. The interviews were carried out to understand the effectiveness of the actors in the chain, as well as the maturity of the companies and the difficulties encountered by entrepreneurs in the edible insect sector in Brazil;

5. Discussion and conclusion—The case studies yielded a practical understanding of the social, economic and environmental conditions of these companies. They elucidated the market transition that one company is currently undertaking, as well as the market positioning that both hope to achieve.

4. Results

4.1. Brazilian Edible Insects Supply Chain

The SWOT matrix was applied to analyze the Brazilian edible insects supply chain. This approach highlights the following:

Strengths:

- Insect farming generates less greenhouse gas than traditionally farmed cattle;
- The reproduction of insects using food waste also facilitates the dissipation of large amounts of organic waste;
- Reduced requirement for fresh fruit and grain flour (as currently used in insect breeding);
- The production of insect protein as a replacement for animal protein will reduce the consumption of red meat, and is more sustainable, healthy and economical;
- Insect farming requires less water than producing the same amount of animal protein.

Weaknesses:

- Legislative bans on insects and insect-based products that are intended for commercialization as food;
- Artificial diets based on food byproducts should be specifically studied for each species of edible insect;
- Only five companies currently work with edible insects.

Opportunities:

- Insects have a promising history of being used to produce proteins and fat, and they serve as an effective source of these two substances, thus helping to combat protein energy deficiency while minimizing the environmental impact of food production.

Threats:

- The presence of substances derived from organic materials (e.g., herbs) that are potentially harmful to insects;
- Cultural impediments to the introduction of edible insects into animal feed;
- The potential for heavy metals and mycotoxins to be bioaccumulated;
- The mechanisms of pesticide, drug and hormonal uptake are uncertain.

4.2. Characteristics of the Companies Studied

The sustainable business model canvas was used as a model for the analysis of companies. In addition to the nine blocks of the traditional business model canvas (customer segment, customer relationship, channels, cost structure, revenue stream, key activities, key resources and capabilities, key stakeholders and value proposition), this model incorporates the 3Ps of value proposition related to sustainability:

- Profit—superior value that is offered to customers compared to competitors;
- People—positive impacts of common interest to society;
- Planet—positive impacts for the environment.

Via the two case studies, it was possible to identify the actors in the chain, their roles, difficulties, and how value is generated.

4.2.1. Value Proposition

Alpha Company

- Profit: The company's value proposition relates to the production of sustainable feed, aiming at preserving the environment, as well as aiding the economic development of several Brazilian communities. The company's ambition is to create mechanisms that can prolong life and restore Brazilian ecosystems. At present, the development in this company of insect processing for animal feed relies on a single pilot plant, but one with high capacity and the potential to become the largest insect processing plant in Brazil and Latin America. The plant will begin serving the aquaculture, poultry and pet sectors of the animal protein market. Wirth a vision of future markets, the company invests in research into the use of insects in the pharmaceutical sector and has an expansive growth strategy extending up to 2027.

- People: The company's strategy is to open up the production process and the technology used in production, contributing to the expansion of the production chain, and consequently to increase employment. To this end, the company will supply insect eggs through partnerships, and will share their cultivation methods with new breeders who will become part of the chain. In this way, it will be possible to impart better living conditions upon small producers, offering these families a better income and a better quality of life.
- Planet: The insect used to produce feed is BSF, which is fed on waste. Organic waste, for example, that was previously sent to landfills, is now reintroduced into a new chain as food. However, the company faces challenges in accessing this waste. Some of these challenges include the cost of transporting the waste to the destination, the collection of large volumes in different locations and the duration for which the waste can be deposited while awaiting collection. Other types of waste can be used, such as brewery waste. However, this waste is about seventy percent water, which makes freight and transport extremely expensive, increasing operating costs. Depending on the type of waste, the logistical strategy changes, as the requirements of waste removal are inconsistent. In addition, the requirements when storing waste in its place of origin also differ from those of its place of origin. To overcome the challenges of waste collection, the company visits market actors involved in composting and landfills, and it has discussions with managers in the urban and organic waste chain. Once these challenges are overcome, the use of waste can contribute to mitigating environmental problems.

Beta Company

- Profit: The company's value proposal is to extinguish hunger and accelerate the ecological regeneration of Brazil, via the production of high-quality protein and oil, thus combining financial profit and sustainability. The company is now exiting the laboratory stage and looking to build a pilot plant for growing and processing BSF, which will be registered with the Ministry of Agriculture. The company's ambition is to become the largest animal feed production company in Latin America. The company enacts the entire process, from the collection of organic waste to the production of flour and insect-based oil used for animal consumption. In addition, the company markets the eggs it produces. As such, the company is involved in the collection of urban waste, in the transformation of this organic residue into substrate, in the fattening of the larvae and in the processing of the larvae for product formulation.
- People: Via the decompression of the protein chain, the company can work towards the fight against hunger by reducing the competition between protein sources for animal feed. When insects are introduced as an integral component of animal feed, it will be possible to guarantee a better supply of protein for people. Furthermore, greater understanding will lead to behavioral changes that will contribute to responsible consumption.
- Planet: At the company's center of operations, approximately three hundred and sixty-six tons of urban organic waste are generated per hour. The work of transforming this waste into substrate for the BSFs further significantly impacts daily waste production, even if to a smaller degree. In this way, organic waste is transformed into yeast for the development of BSF larvae, which are the raw materials for dog, cat and ornamental fish feed. As these animals' diets compete with human diets over the same protein sources, the proposal is to reduce the pressure on the protein production chain, enabling a reduction in the use of natural resources.

4.2.2. Value Creation

Alpha Company

- Key stakeholders: The company is partnered with universities for biological and engineering research. This partnership is based on a win–win theory. As a result of this collaboration, the company incurs no costs in laboratory research. In addition, the company's interns use the universities' laboratories for research. In the production of BSFs, the company is partnered with another company that specializes in organic protein production. In addition, the company is also partnered with the Brazilian Micro and Small Business Support Service (SEBRAE), which facilitates national and international fairs, increasing the company's visibility.
- Key activities: As the BSF processing methodology is not yet perfected, the company offers insects to other companies that produce biological agents. Further, they encourage the use of insects in different stages of their life cycle as food—including pulps, young insects and adults. The company undertakes the entire rearing process, separates, weighs and packs them, issues invoices and dispatches the insects to the end customer.
- Key resources and capabilities: The company's greatest resource is the formula with which they feed the insects, which comprises wheat bran, cornmeal and corn, in addition to hydrated vegetables. Another important resource is knowledge of the parameters of the breeding process, such as temperature and humidity. This knowledge was originally acquired experimentally, and continues to be improved since the ideal production model remains unknown.

Beta Company

- Key stakeholders: The main business partner is in the organic food composting sector, and this company is located in the same place as Beta company. Thus, the logistical costs are very low. This partner is also a co-founder of Beta company. The company also has partnerships with rural federal universities.
- Key activities: The company currently produces fresh insects to meet animal production needs.
- Key resources and capabilities: The company's main resources are the equipment and physical space that comprise the factory, in addition to labor.

4.2.3. Delivery of Value

Alpha Company

- Customer segment: The company has three customer segments. The first segment is customers who buy live insects and resell them for animal feed. The second segment is the final customers, who buy the insects to feed their pets. The third segment is customers who use the insects as biological agents.
- Relationship with customers: As the market is small, the relationship with customers is close. Due to its origins as a family business and its few employees, customer needs are addressed promptly.
- Channels: The most commonly used communication channels are social networks and WhatsApp. The company has a website that is currently being restructured, as the company's business model is undergoing development.

Beta Company

- Customer segment: When the company's plant is up and running, the main customer segment will be feed producers. Subsequently, the company will have its own feed line, mainly for domestic animals.
- Relationship with customers: The relationship with customers will be developed as the company matures. However, the company is already positioned in the market, and sells live insects.

- Channels: The company has a structured website, through which it is possible to contact them and ask questions about the products offered. It is also possible to contact the company by email and LinkedIn.

4.2.4. Value Capture

Alpha Company

- Revenue stream: All three market segments offer similar revenues. However, the revenue source offering the highest margin is the segment of final customers who buy insects to feed their non-conventional pets. This market is seasonal, depending on the type of animal; for example, frogs are fed live insects only in parts of their life cycle.
- Cost structure: The company's biggest costs are raw materials and labor. Under the new model of producing insect-based feeds, the biggest cost will be the processing of the feed.

Beta Company

- Revenue stream: The company's revenue is negligible, as it is still under development. However, the company predicts that 80% of its revenue will come from insect flour.
- Cost structure: The highest costs are related to the construction of the factory and the purchasing of equipment for BSF production, as well as electricity and general maintenance.

5. Discussion

Brazil's edible insect supply chain will play a significant role in circular sustainable agriculture via its capacity for closing nutrient and energy loops, promoting food security and minimizing climate change and biodiversity loss. These aspects strengthen the chain and are associated with the achievement of the Sustainable Development Goals.

The network is still young and disorganized, as only five companies are in operation and there are some factors that contribute to slowing development, such as legal obstacles against and a lack of legislation for insect-based products, and the lack of cultural acceptance of the consumption of insects in Brazil, as verified in the weaknesses section and pointed out by others [20]. Another characteristic of this chain is that the companies work independently and autonomously; that is, each performs all parts of the production process, and there is no network of collaboration among them.

The case studies presented elucidate certain as-yet-unmet opportunities to contribute to the sustainable development of the chain, such as the use of land for soybean planting; reducing water consumption and greenhouse gas emissions; replacing animal proteins, and reducing organic material, among others.

The sustainable business model canvas enabled us to analyze how both companies are structured. Despite only focusing on two case studies, the conditions of these companies reflect the contemporary condition of the value chain associated with the production of edible insects for animal feed in Brazil. As such, we can conclude that the chain is still young and that its development will be complex, since the production process is still under development.

As regards the business models, we can observe adhesions between practice and theory. The following constitute the pillars of the business model.

Value proposition: The companies' value propositions reflect concerns about the planet, and especially about the future demand for protein and the competition that will arise between food and feed, as well as the demand for fishmeal for fisheries [5]. The desire to preserve the environment has encouraged businessmen to seek new solutions in structuring the animal feed market. However, international research on the protein capacity of insects, as well as millionaire-funded projects, have been decisive in encouraging investment in a new market, which features sustainability as its main motivation.

Similarly to Europe [15], in Brazil, insect-based protein products still cannot compete with established protein sources, in terms of costs. Further, agrofactories still do not have the capacities or consistency in quality required for processing.

As identified by [22], some insects can play dual roles within the chain, such as via the recycling of organic by-products into compost fertilizers, and this is also the case for BSFs. BSFs consume waste as a source of energy, and this offers numerous benefits to a developing country that is facing difficulties in the collection of urban waste and has little infrastructure for selective collection.

Furthermore, as described in [6], the chain of using insects as animal feed in Brazil begins with bio-waste, but currently ends with insect processing, given that both the active companies still do not produce processed feed for poultry, pork, or fish. The next steps will be to develop the poultry, fish, pork and pet (i.e., dogs and cats) markets via feeding with processed feed.

Despite the entrepreneurs' willingness to reveal their secrets related to the cultivation of insects, certain aspects related to processing remain concealed, as well as the technology used. Both companies are currently undertaking test phases, and their industrial plants are still in the pilot phase. As such, it is not possible to guarantee, despite the energy expended on research, that their models will work. To arrive at the most optimal model, more tests and improvements will be required until the whole process is matured.

The creation of value in companies is based on partnerships. The chain is developed through strategic partnerships. However, there are differences in the types of partnerships. To produce BSFs, Alpha company is partnered with another that specializes in organic protein, and this company invests in technology and capital; on the other hand, Beta company's main partner is an organic food composting company. In addition, Beta company has gone public, and thus receives investments from private individuals.

Despite BSFs showing promise and representing a good investment for Brazilian businessmen, there is a logistical bottleneck associated with the cost of feeding them, and this represents one of the biggest challenges for the chain. Beta company encounters fewer difficulties due to its partnership, while Alpha company must search for waste depository locations and logistical strategies, even though there are several sanitary landfills in Brazil, as shown in Figure 4.

Figure 4. Guatapará landfill in São José do Rio Preto, São Paulo. Source: personal field research archive.

6. Conclusions

Our analysis of Brazilian companies active in the production of insects for animal feed in Brazil has allowed us to understand the current organizational condition of these companies. Just as international research on the subject is underdeveloped, the companies involved are also young, with Alpha being the most experienced in the sector, but having only been on the market for seven years.

The young age of the sector explains the characteristics observed in the Brazilian chain, such as the high degree of underdevelopment in terms of financing, technology and the qualification of human resources; the disorganized supply chain and supplier structure; the efforts being made by regulatory agencies to develop regulations relating to the production and use of insects in animal feed, which, in turn, should encourage those interested in this innovative venture into further research and development.

As shown in previous surveys undertaken in other countries and in Brazil, for BSFs to be integrated as an animal feed that can reduce organic waste in a sustainable way, companies must invest time and financial resources into research focusing mainly on BSFs, according to the characteristics of this species. However, despite these investments, in Brazil, as well as in Europe, insect-protein-based products are still not competitive compared to established protein sources in terms of cost. The non-competitiveness of the Brazilian chain makes it difficult for it to develop a market that is regulated in terms of prices, products, supply and demand.

Because the productive chain is still in its nascent stages, several aspects of the business model are still being developed, as well as the teams, processes, labor, technology and space required. Further, more time will be required to allow the maturation of the blocks that make up value delivery and capture, further characterizing the difficulties encountered in the Brazilian chain in establishing itself and becoming competitive.

The companies' strategies for dealing with this process were not revealed. However, Alpha company seems to be employing a "homemade" strategy, founded on the time it has spent in the market and its acquired experience. Beta company, on the other hand, seems to believe that investing in advanced technology is the safest path. It will soon be clear which of these strategies is best.

The concepts of sustainability and environmental regeneration increase the value of the benefits offered by companies. However, both these companies desire a market that will grow annually, which is why they are currently racing to be the first to establish processed BSF for use in animal feed. The conditions in Brazil are optimal for the growth and production of BSF, as a large volume of organic waste is generated daily and the species is native to this country.

Previous research and our study of the Brazilian edible insect production chain together indicate that the value chain holds great promise and presents several opportunities. These mainly relate to sustainability, since the development and advancement of the chain will contribute to a reduction in the use of natural resources, being an alternative source of protein and a substitute for traditional feed and allowing for the recycling of organic products into compound fertilizers, thus contributing to the Planet, Profit and People model.

The use of insects as animal feed is related to several SDGs, but specifically to SDGs 2 (Zero Hunger and Sustainable Agriculture), 12 (Responsible Consumption and Production) and 13 (Action Against Global Climate Change), in addition to 6 (Drinking Water and Sanitation) and 14 (Life in Water).

Author Contributions: Conceptualization, J.G.C.G. and M.T.O.; methodology, J.G.C.G. and E.L.U.; investigation, J.G.C.G.; original draft preparation, J.G.C.G.; writing—review and editing, M.T.O. and H.d.C.L.d.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received in part external funding by the Coordination for the Improvement of Higher Education Personnel—Brazil (CAPES)—Finance Code 001.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: Special thanks to the companies that participated in the interviews, allowing us to obtain the data used for this study.

Conflicts of Interest: The authors declare no conflict of interest.

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APÊNDICE D – Artigo 4

Key Performance Indicators (KPI) in the Edible Insect Value Chain: An Integrated Analysis from a Brazilian Perspective

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ABSTRACT

Brazil's still-nascent edible insect sector is increasingly viewed as a practical way to ease global food security pressures. The present research devised and tested a set of performance metrics that center on production efficiency, market competitiveness, and environmental stewardship. Guided by the Handbook for Value Chain Research, a mixed-methods design combined quantitative techniques—Spearman correlation and Exploratory Factor Analysis (EFA)—with qualitative inquiry. Data were obtained through a structured questionnaire administered to members of ASBRACIA (Brazilian Association of Edible Insect Producers). The analysis highlighted five performance indicators with both high centrality in the interaction network and strong statistical significance: (i) quality of relationships with suppliers, (ii) effectiveness of market segmentation, (iii) accuracy of price forecasting, (iv) competitive advantage, and (v) efficiency in converting inputs into final products. These indicators are tightly inter-linked, indicating the need for coordinated planning across production stages to reinforce sector development. The resulting analytical model—tailored to the Brazilian context yet transferable to other settings, including developing economies and value chains comprising firms of varying sizes—offers actionable insights for entrepreneurs and policymakers seeking to consolidate insect-based proteins as a sustainable alternative.

Keywords: KPI, value chain; edible insects; performance indicators; production efficiency; food-system sustainability

1 INTRODUCTION

Natural ecosystems face mounting pressure just as the world's appetite for protein keeps expanding. Agriculture already covers about 38 % of Earth's land, with roughly two-thirds of that area devoted to livestock pasture—one of the chief causes of soil degradation and biodiversity loss (FAO, 2020; FAO, 2021). Therefore, identifying protein sources that demand fewer resources and leave a smaller environmental footprint is essential (FAO, 2013).

Insects intended for human consumption and animal feed are increasingly considered realistic options in this quest. Studies highlight, for instance, the Black Soldier Fly (Hermetia illucens), the common housefly (Musca domestica), and the mealworm (Tenebrio molitor), all capable of turning low-value organic residue into protein-rich biomass, a process that dovetails with circular economy ideals (FAO, 2013; NAYAK et al., 2024).

Sustaining that growth, however, calls for decision-support tools that can guide producers and investors alike. Evaluation methods range from concise stage-by-stage checklists to comprehensive frameworks that follow material flows from rearing units to processing and final distribution (SPYKMAN et al., 2021; VELDKAMP et al., 2012).

Within Brazil, the chain still grapples with informality, small production scales, gaps in skilled labor, and, crucially, the lack of a dedicated regulatory framework (GOMES et al., 2023).

Key performance indicators (KPIs) can close part of this gap by measuring efficiency at each link—from production to market entry—and pointing to strategic improvements. Yet systematic KPI frameworks remain scarce in emerging chains such as edible insects.

This study develops and validates a KPI set tailored to Brazil's insect sector and, through quantitative statistical techniques, maps how those metrics interact to reveal the drivers of efficiency, competitiveness, and sustainability.

Based on this, the research question guiding this study is: Which KPIs display the most extraordinary centrality and interdependence within Brazil's edible-insect value chain, and in what ways do those connections foster systemic productivity and help consolidate the sector as a sustainable protein alternative?

2. THEORETICAL FRAMEWORK

Edible insect production is part of a wider transformation of global food systems, driven by the push for sustainable and circular solutions. The discussion reviews the core theories on how insects fit into this model, highlighting their nutritional value and the main structural steps that make up their production chain.

2.1 Introduction to the Potential of Insects in the Circular Economy

Recent studies consistently show that farmed insects can remarkably efficiently turn low-grade organic residues into protein-rich biomass. Large-scale production still lags behind conventional livestock, yet strong interest from scientists and producers suggests these organisms will occupy a strategic place in future sustainable supply chains (Sun-Waterhouse et al., 2016; Cortes Ortiz et al., 2016).

Tenebrio molitor is particularly noteworthy for turning nutritionally poor substrates into protein-rich meals. If production costs fall, mealworm flour could replace soybean meal in compound feeds, combining economic feasibility with environmental gains (Cortes Ortiz et al., 2016).

Another promising candidate is the larva of *Hermetia illucens*. Beyond transforming residues—including manure—into high-value protein for animal diets, its crude fat can be processed into biodiesel, expanding its reach within circular-economy frameworks (FAO, 2013). However, limitations remain, such as the significant energy required to maintain optimal rearing temperatures, which restricts adoption in temperate regions (Veldkamp et al., 2012).

Nutritionally, edible insects provide balanced profiles of vitamins and micronutrients, making them attractive, functional ingredients for human and animal nutrition (Rumpold & Schlüter, 2013a). Composition depends heavily on the rearing diet: recent work shows that secondary agricultural streams can supply more sustainable, cost-effective feed, improving the zootechnical performance of *Hermetia Illucens*larvae (Nayak et al., 2024).

Environmental metrics reinforce these advantages. Insect farming emits fewer greenhouse gases and uses less water and land than traditional livestock systems (Rumpold & Schlüter, 2013b). Figure 1 quantitatively presents the environmental superiority of insects —

particularly mealworms — compared to conventional animal protein sources (OONINCX & DE BOER, 2012; WILKINSON, 2011).

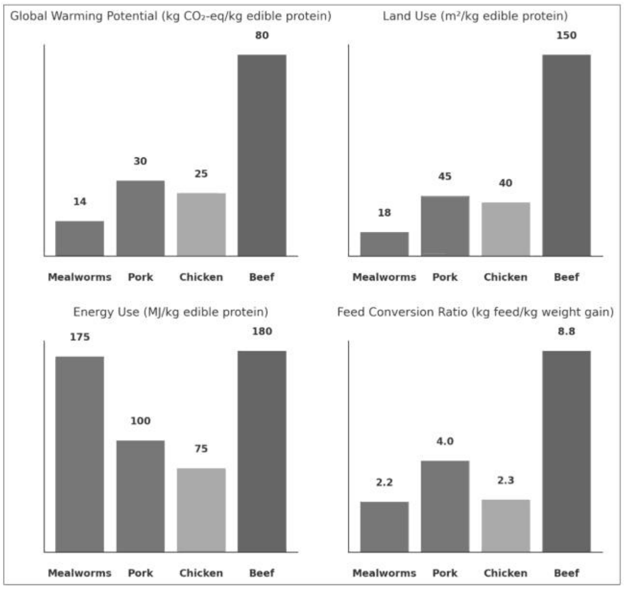

Figure 1 – Comparison of Environmental Impact and Feed Efficiency Among Different Animal Protein Sources
Note: The values presented in the table correspond to the minimum values reported in the literature by Oonincx & De Boer (2012) for the metrics of global warming potential, land use, and energy use. The Feed Conversion Ratio was extracted from the study by Wilkinson (2011).
Source: Adapted from Oonincx & De Boer (2012) and Wilkinson (2011)

The graphs highlight that those insects — particularly Tenebrio molitor's global-warming potential averages 14 kg CO_2-eq per kilogram of edible protein versus 80 kg CO_2-eq for beef, while land occupation drops from roughly 150 m^2/kg (cattle) to 18 m^2/kg (mealworms) (Oonincx & De Boer, 2012; Wilkinson, 2011). Feed conversion is likewise more efficient — mealworms require about 2.2 kg of feed per kilogram of weight gain, whereas cattle need 8.8 kg.

Coupled with high fecundity, efficient feed utilization, and modest space requirements, these traits position edible insects as a compelling, sustainable alternative to established animal protein sources such as meat and fishmeal (Rumpold & Schlüter, 2013a).

2.2 Challenges and technologies in the insect production

Although insect farming brings clear environmental gains, sustaining the right climate inside the facility remains a significant hurdle. One promising route is to capture the metabolic heat generated by the insects themselves; paired with well-designed ventilation and climate-control systems, this strategy can trim external energy demand and improve economic viability. Therefore, facility layout and equipment choice figure prominently in any cost-effective design (Oonincx & De Boer, 2012; Cortes Ortiz et al., 2016).

Feed formulation represents a second, equally pressing challenge. As the industry matures, attention is shifting toward diets built from readily available ingredients that carry a lighter environmental footprint—often biological waste streams destined for disposal (Cortes Ortiz et al., 2016). Long-term success will hinge on balancing low-cost inputs and strict environmental safeguards without undermining animal performance (Li et al., 2023).

Nutrition underpins both productivity and product quality. Like conventional livestock, insects need rations that deliver the right balance of nutrients to support growth and ensure consistent biomass composition. Effective feed management becomes critical when perishable agricultural by-products are used, as timely delivery and minimal spoilage help sustain yields and guard against contamination (Halloran et al., 2016; Cortes Ortiz et al., 2016).

Running a modern insect facility increasingly hinges on automation. Producers now fit their sheds with real-time monitors for temperature, humidity, and other essentials, keeping the rearing climate in the sweet spot and protecting daily output (Cortes Ortiz et al., 2016).

The production cycle unfolds over a series of clearly defined stages—each with its quality checkpoints—to keep the process efficient and the final product safe (Costa et al., 2021). Table 1 summarizes these stages, from input selection to distribution, drawing on multiple sources (Costa et al., 2021; Spykman et al., 2021; International Platform of Insects for Food and Feed (IPIFF), 2022).

Module	Production Stages	Description
Primary Feed Production	Raw materials	Entry, mixing, and storage of feed substrate for the insects.
	Ingredient processing	Substrates are selected according to the nutritional composition required for each species and transformed into feed ingredients.
Larval Growth Phase	Larvae-seed production	Production of adult colonies and egg laying.
	Feed management	Management of feed distribution to larvae.
	Climate control	Control of temperature, humidity, confinement, and ventilation.
	Sanitary management	Good practices for facilities and production control, such as structural design, pest control, and hygiene protocols.
Insect Processing	Separation	Separation of larvae from the residual substrate. Methods vary by species and include sifting or natural migration.
	Slaughter	Common methods include heat treatment (scalding) and freezing to preserve nutritional value.
	Processing	Includes grinding (converting insects into powder or meal) and derivative extraction (proteins, oils, chitin) using physical, chemical, or biochemical methods.
	Packaging	Follows standards to avoid contamination, including labeling with product name, expiration date, and nutritional information.
Residual Biomass	Compost production	Residual biomass (frass) is used to produce compost, avoiding traditional composting.
Distribution	Storage and sales	Includes proper transportation, storage, and sale of the final product

Table 1 – Stages of Edible Insect Production and Processing
Source: Adapted from Costa et al. (2021), Spykman et al. (2021), and IPIFF (2022)

According to Table 1, the overall efficiency of the value chain relies on the integrated contribution of all stages, working together to ensure the effective conversion of organic waste into high-value biomass. Standardizing procedures and adopting best practices—especially in sanitary and processing controls—are essential to ensure food safety and the quality of final products.

Appropriate technology is required at each processing juncture to win broader acceptance of insects as food—rearing, feeding, handling, harvesting, processing, and packaging. Tight standardization across those steps underpins food safety and consumer confidence (Sun-Waterhouse et al., 2016).

Food safety assurance includes vigilant screening for microbiological, chemical, and physical hazards. International standards demand strict protocols plus ongoing monitoring throughout the production chain (Li et al., 2023; Rumpold & Schlüter, 2013a).

Finally, valorizing residual biomass—turning leftover material into fertilizers—offers an additional boost to both economic and environmental performance, reinforcing the sector's circular economy credentials (Spykman et al., 2021; Cortes Ortiz et al., 2016).

2.3 Types of Insects and Derived Products

Several Orthopteran insects—particularly crickets and grasshoppers—contain protein comparable to casein and soy, supplying the full complement of essential amino acids needed for human health (Rumpold & Schlüter, 2013a). Within Western industrial settings, three species stand out: the black soldier fly (Hermetia illucens), the common housefly (Musca domestica), and the mealworm (Tenebrio molitor). Their high protein and fat concentrations make them credible substitutes for fishmeal and soybean meal in feed formulations (Veldkamp et al., 2012). Table 2 contrasts these larvae's crude protein and fat contents (dry-matter basis) with conventional feed ingredients.

Protein Source	**Crude protein (%)**	**Crude fat (%)**
Hermetia illucens	35-57	35
Musca domestica	43-68	4-32
Tenebrio molitor	44-69	23-47
Fishmea	61-77	14-17
Soybean meal (defatted)	49-56	3

Table 2 – Protein and Fat Content in Insect Larvae and Conventional Feed Sources
Source: Adapted from Veldkamp et al. (2012)

The data in Table 2 suggest that insect meals frequently match or exceed the protein content of traditional sources, while their variable lipid levels allow for flexible diet design. Taken together, these characteristics underline insects' versatility and their fit with circular economy principles.

Among commercially reared candidates, *Hermetia illucens* has received particular attention because of its ability to turn organic waste into nutrient-dense biomass. Productivity rises markedly when temperature, larval density, and substrate composition are optimized—parameters now considered critical leverage points in scaling sustainable protein supply chains (Nayak et al., 2024).

Consumer interest has broadened the global portfolio of farmed species to include grasshoppers, ants, silkworms, and cicadas, spurring new investment and product diversification. At the same time, rising prices for conventional protein sources have accelerated the hunt for alternatives. Insects have gained popularity among athletes and fitness enthusiasts who favor high-quality proteins with a smaller environmental footprint—an emerging trend that has fueled market growth (Fortune Business Insights, 2025).

Roughly 2,000 insect species are eaten worldwide, and food companies now incorporate insect ingredients into protein bars, snacks, biscuits, pasta, and even confectionery (Mordor Intelligence, 2024). Processed formats often improve consumer acceptance by masking sensory traits that might otherwise deter first-time users (Li et al., 2023).

Successful mainstream adoption of *Hermetia Illucens* and *Tenebrio molitor* depends on year-round, cost-effective production of uniform, high-quality biomass. Techniques that convert insects into stable protein meals are essential for product standardization and food safety assurance; without such refinements, the competitiveness and scalability of insect farming will remain constrained (van Huis, 2013).

2.4 Insect market: segments, geography, competitiveness, and regulations

The worldwide trade in insect-based ingredients has skyrocketed, from an estimated USD 1.89 billion in 2024 to a projected USD 2.91 billion by 2029—a clear sign that alternative proteins are gaining mainstream traction (Mordor Intelligence, 2024).

Current product lines fall into three categories: whole insects, insect powder, and insect meal. Interest in insects has risen sharply as consumers gravitate toward minimally processed foods; firms now offer dried, raw, and ready-to-eat formats to meet this demand (Fortune Business Insights, 2025).

Protein manufacturers serving the aquafeed sector have likewise looked to insect meal as a substitute for fishmeal and soybean meal, particularly as global aquaculture expands and the need for sustainable feed sources becomes more urgent (Mordor Intelligence, 2024).

Regional patterns differ. In many tropical countries, entomophagy is rooted in local traditions, though still practiced primarily at the household scale. Acceptance has grown more slowly in temperate zones such as North America and Europe, where interest in sustainable diets is the primary driver. By contrast, Asia–Pacific—helped by low logistics costs, plentiful raw materials, and expanding production infrastructure—has emerged as the fastest-growing market (Fortune Business Insights, 2025).

Effective coordination among government, industry, and the research community remains essential (van Huis, 2013). Figure 2 depicts this three-way interaction and each sphere's distinct contribution to the insect value chain.

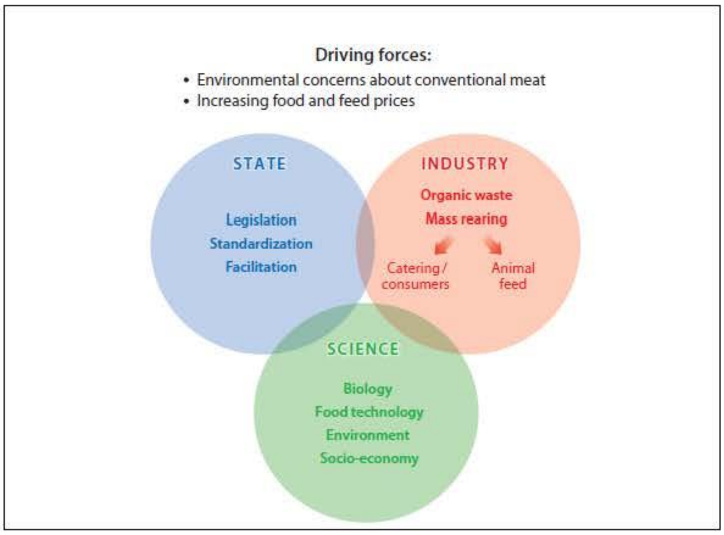

Figure 2 – Interface Between Government, Industry, and Science in Promoting Insects as Food and Feed
Source: Van Huis (2013)

As Figure 2 illustrates, public agencies lay down the legal rules, draft standards, and roll out incentives that nudge product development forward. The industry's part is to scale up, turn waste streams into raw material, and shape offerings that work in both feed and food markets. Science supplies the underpinning knowledge—biotechnology, food engineering, sustainability metrics, and socioeconomic analysis—needed to support innovation and best practices (Li et al., 2023; van Huis, 2013). When these three spheres work in concert, insect-based proteins can gain full acceptance as a sustainable and economically viable option on a global scale.

Perceptions shaped by culture add another layer of complexity. In places where entomophagy is long-standing—China, for example—acceptance is noticeably higher, while many Western consumers remain hesitant (Hartmann et al., 2015). Targeted information campaigns that emphasize nutritional and environmental gains and product tweaks that better match local tastes have proven helpful in easing such reservations (Li et al., 2023).

Progress also depends on a robust, internationally harmonized regulatory framework. Clear safety, quality, and sustainability guidelines are still lacking, and their absence hampers broader adoption. Establishing uniform production, marketing, and labelling rules would provide the certainty needed for long-term sector growth (Fortune Business Insights, 2025).

Several firms—Coalo Valley Farms, Aspire Food Group, All Things Bugs LLC, and Beta Hatch Inc.—continue investing in new product lines, broadening consumer choice and reinforcing market visibility. Moves like these from the corporate side are crucial for persuading the broader market that insects are a serious, reliable protein option (Fortune Business Insights, 2025).

2.5. Development and consolidation of the edible-insect value chain

Although insect-based foods show real potential as a sustainable protein source, the industry still faces several hurdles before it can fully establish itself. Tackling those challenges requires collaboration across every link in the chain so that profitability and environmental stewardship advance in tandem (Li et al., 2023).

Viewing the sector through Kaplinsky and Morris's (2001) value-chain framework makes it easier to see where value is created and where bottlenecks slow progress—insights that can sharpen competitiveness on the world stage. Bermúdez-Serrano (2020) notes that chain configuration differs by context: in some regions, it follows long-standing traditions, while in others, it is still taking shape. In broad terms, however, four core stages tend to recur:

1. Input supply – providers of organic by-products and specialized feed ingredients.
2. Insect production – ranging from wild harvesting and smallholder units to industrial-scale farms.
3. Processing – firms that turn insects into intermediate ingredients or finished goods for food, feed, pharmaceutical, and cosmetics markets.
4. Distribution and consumption – retail channels (street markets, supermarkets, restaurants, e-commerce) and the end users they serve, locally or abroad.

Mapping these stages and their points of interaction makes it possible to streamline operations, trim costs, and raise product quality. A systemic view also encourages producer specialization and the uptake of technological innovation—both critical for building an efficient, sustainable, and competitive value chain on the global stage (Kaplinsky & Morris, 2001).

2.6 Productive efficiency in the edible insect value chain

The insect production chain follows a circular logic: organic residues become nutrient-rich biomass for feed and food, trimming resource use and protein supply's environmental burden (FAO, 2013). Table 3—adapted from FAO—summarises the chain's main building blocks.

Component	Description
Large-scale reproduction	Insect farming systems that use organic waste as a feed substrate.
Large-scale extraction	Extraction processes to obtain proteins, fats, and bioactive compounds from insects.
Ingredients for animal feed	Production of high-protein feed for aquaculture, livestock, and other zootechnical applications.
Ingredients for human consumption	Direct consumption or use as an ingredient in processed foods.
Pharmaceutical and non-food ingredients	Compounds extracted for use in pharmaceuticals, cosmetics, or biotechnology.
Organic waste input	Use of agriculture, food, and other by-products as raw materials.

Table 3 – Components of the Insect Supply Chain
Source: Adapted from FAO (2013)

Each element in Table 3 contributes to turning waste streams into high-value products, pushing the entire system toward greater sustainability. Precise segmentation also lets participants specialize, raising process efficiency and sharpening competitiveness.

To rival staple proteins such as fishmeal and soybean meal, the insect-ingredient sector must produce at an industrial scale. Key levers include fast growth, favorable feed-conversion ratios, disease resistance, and a high degree of process automation (Veldkamp et al., 2012; van Huis, 2013). Optimization extends beyond floor space: automated sensors and controls that track temperature, humidity, and other critical variables are now indispensable for keeping zootechnical performance on target (Cortes Ortiz et al., 2016).

Because insects are ectotherms, even modest swings in the rearing environment can dent feed efficiency, slow growth, or raise mortality. Robust climate-control systems—often tied to real-time monitoring—underpin productivity and process stability (Cortes Ortiz et al., 2016).

As production expands, decision-support tools become vital for steering growth along sustainable lines. Researchers have used everything from quick screening models to complete life-cycle assessments that track impacts across the entire chain (Spykman et al., 2021; Veldkamp et al., 2012).

Standardizing operations is equally important, particularly in automation, pathogen management, and contaminant control. Long-term partnerships between producers and input suppliers can secure consistent quality, curb costs, and speed product development (van Huis, 2013; Johnsen, 2009).

Comprehensive assessment instruments help benchmark competing production systems (Veldkamp et al., 2012). Value-chain analysis—originally detailed by Kaplinsky and Morris (2001)—is one such tool. Showing where value is gained or lost guides efforts to boost energy efficiency and overall sustainability. Integrating edible insects into global markets requires a chain-wide perspective that pinpoints value-adding opportunities; indicators from that analysis reveal not just production efficiency but also how wealth and knowledge circulate among stakeholders.

3. METHODOLOGICAL PROCEDURES

3.1. Methodological approach

As Kaplinsky and Morris (2001) outlined, value-chain analysis frames the entire study. A mixed-methods design couples quantitative techniques to measure interactions among chain stages with qualitative inquiries that shed light on producer profiles (size, purpose, farmed species, marketing channels, and target segments). Treating the two strands together yields a fuller picture of performance and delivers information that can guide decisions across Brazil's edible-insect sector.

3.2. Methodological structure

Three analytical dimensions shape the investigation: (i) Value-Chain Mapping, (ii) Product Segmentation, and (iii) Access to Final Markets (Kaplinsky & Morris, 2001). Each dimension breaks down into variables that later became the backbone of a 33-item closed-ended questionnaire.

Dimension 1 – Value-Chain Mapping: this section charts material, service, and information flow:

- Production values: total output and profit, calculated from self-reported operating costs.
- Physical goods flow: movements of substrates, intermediates, and finished goods (see Table 1).
- Specialized services: the part played by consultancy, training, and knowledge transfer.
- Employability: job types created and wider socioeconomic effects.
- Sales destinations: main marketing channels and consumption patterns.
- Foreign trade: export and import activity.

Dimension 2 – Product Segmentation: variables reveal how producers tailor offerings for distinct customer groups:

- Market niches: clusters of consumers who share preferences or behavior.
- Market volatility: shifts in demand, price swings, and regulatory pressure.

Dimension 3 – Access to Final Markets: the third block explores competitive positioning:

- Main buyers: client mix, market structure, and concentration.
- Buying-function dynamics: supplier-selection criteria and bargaining power.
- Supply-chain management: diversification strategies, relationship building, and logistics.

3.3. Data collection and instrument validation

An initial 65-item open-ended questionnaire—drafted to probe every key variable—was reviewed by specialists at a Hermetia illucens biofactory. Redundant items were removed and wording refined, producing a final version with five demographic multiple-choice questions and 33 statements rated on a five-point Likert scale (1 = "not present in my business," 5 = "excellent").

A small-scale pilot at a Tenebrio molitor farm tested whether the questions were clear in practice. Participant feedback prompted several wording and grammar adjustments to improve readability. With ASBRACIA's support, the revised survey was emailed to all member producers, broadening participation.

3.4. Data analysis

Responses were converted into performance indicators by pairing each questionnaire item with a metric, such as quality of supplier relationships, market segmentation effectiveness, price forecasting accuracy, perceived competitive edge, and efficiency in converting inputs into finished goods. Analysis ran in three steps:

- Profile characterization based on operational and market descriptors.
- Spearman correlation to uncover statistical links among indicators.
- An Exploratory Factor Analysis (EFA) was run to uncover hidden patterns in the data and cluster variables that behaved similarly.

Table 4 sketches the research blueprint by listing the three analytical dimensions alongside their variables, value-chain stages, and indicators. That map guided every phase—from data gathering to interpretation—so the work stayed anchored to its original goals.

Handbook Dimension	Handbook Variables	Value Chain Stages	Indicators
Value Chain Mapping (Identifies and analyzes the variables and relationships that shape a specific value chain)	Production values	Production and cost efficiency	Production variation Production cost efficiency
	The physical flow of goods	Acquisition of feed inputs – raw materials	Raw material accessibility
		Insect growth – seed larvae production, feed management, climate control, sanitary management	Reproductive management efficiency Feed substrate preparation efficiency Initial larval survival Climate stability in production units Production sanitary control
		Processing and packaging – separation, slaughter, processing type, packaging	Larva-waste separation efficiency Slaughter process efficiency Efficiency in the Transformation into Final Products Packaging sustainability
		By-product utilization – compost production (frass)	Residual biomass utilization rate Commercial utilization of frass
		Distribution and logistics – storage and sales	Logistics efficiency
	Specialized service flow	Specialized services and consulting	Impact of specialized services
		Training and development	Training program effectiveness
	Employability	Workforce and diversity	Gender diversity and equity in the workforce
	Sales destination	Regional expansion	Regional expansion efficiency Customer growth and retention
		Customer growth	Regional expansion efficiency Customer growth and retention
	Foreign trade	International trade and origin of inputs	Revenue from exports Domestic vs. imported input ratio

<table>
<tr><th>Handbook Dimension</th><th>Handbook Variables</th><th>Value Chain Stages</th><th>Indicators</th></tr>
<tr><td rowspan="4">Product Segmentation
(Divides the end market into distinct groups or segments based on specific characteristics that differentiate consumers or their demands)</td><td>Market niches</td><td>Market positioning</td><td>Adaptation to diversified markets
Effectiveness of market segmentation</td></tr>
<tr><td rowspan="3">Market volatility</td><td>Price management</td><td>Accuracy of Price Forecasting</td></tr>
<tr><td>Market competitiveness</td><td>Competitive advantage in the market</td></tr>
<tr><td>Regulatory environment</td><td>Adaptability to regulatory changes</td></tr>
<tr><td rowspan="4">Access to Final Markets
(Understands how producers, especially in developing economies or emerging sectors such as edible insects, can compete and enter highly competitive global markets)</td><td>Main buyers</td><td>Commercial risk and dependency</td><td>Customer base diversification
Sales to strategic clients</td></tr>
<tr><td>Buying function dynamics</td><td>Sales strategies and channels</td><td>Effectiveness of marketing and sales strategies
Diversification of sales channels</td></tr>
<tr><td rowspan="2">Supply chain management</td><td>Supplier management</td><td>Supplier base diversification</td></tr>
<tr><td>Supplier relationships</td><td>Quality of supplier relationships</td></tr>
</table>

Table 4 - Methodological Structure: Relationship Between Dimensions, Variables, and Value Chain Stages of Edible Insects

Source: Adapted from Kaplinsky, R.; Morris, M. *A Handbook for Value Chain Research*. 2001. With author's additions.

Table 4 provides a synthetic overview of the methodological structure that guided the development of the research instrument and the analysis of the edible insect value chain in Brazil. In practical terms, the table links each dimension from the Handbook for Value Chain Research to the variables examined and the field stages defined for data collection, exactly as the manual suggests. Those variables were then measured through the questionnaire itself. Setting out the work this way lets the study capture technical and production details and market and relationship dynamics, creating a solid base for the following statistical tests.

4. RESULTS AND ANALYSIS

4.1 Profile of edible insect producers in Brazil

The respondent pool (n = 17) showed considerable diversity. Under SEBRAE's size criteria, most operations fell into the individual micro-entrepreneur category (58.8 %), while 29.4 % qualified as micro-enterprises. Production is geared chiefly toward animal feed (41.7 %), with fertilizer manufacture (22.2 %) and human-food applications (13.9 %) following behind.

Species choice proved similarly concentrated: Hermetia illucens appeared in half of the businesses surveyed, and Tenebrio molitor in 45.5 %. Regarding product form, live insects dominated sales (31 %), whereas processed and dehydrated items accounted for 27.6 %. Pet food (35.3 %), poultry farming, and aquaculture (20.6 %) were the chief market outlets. Figure 3 presents these findings in visual form.

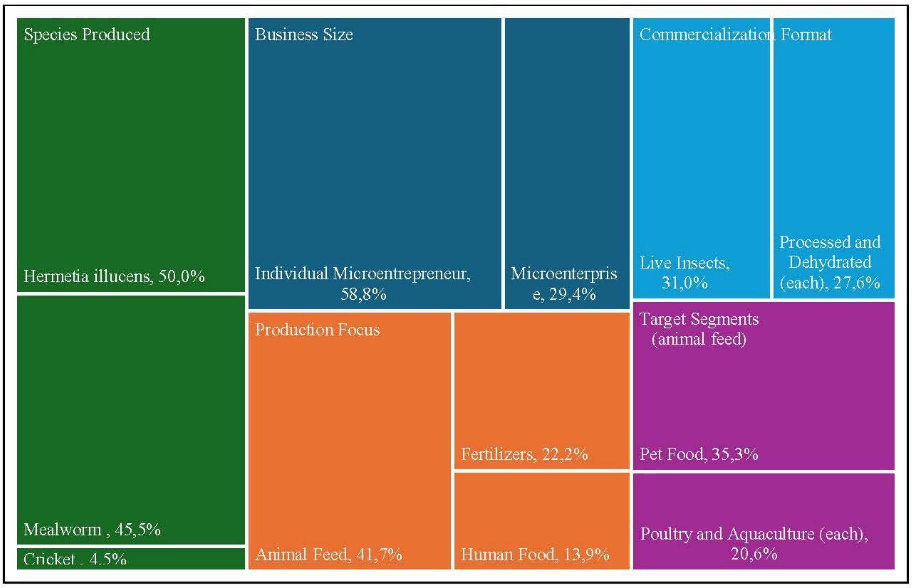

Figure 3 – General Profile of Respondents
Source: Research data

Figure 3 also points to an industry that is still finding its footing. Limited production scale and the absence of clear regulatory pathways make formalization difficult. While Brazilian law does not forbid humans from eating insects, the lack of specific rules means no companies can secure official licenses; many operate informally or restrict their activities to research projects and on-farm use.

4.2 Integrated statistical analysis

Spearman's rank-order test—well suited to the Likert-scale data—revealed a network of strong associations ($r > 0.7$; $p < 0.05$) among several indicators; this pattern points to a close-knit set of relationships within the value chain.

Each indicator's influence was then summarised in a centrality score, calculated as the count of statistically significant links it held with other variables. Scores were classed as high (above the 75th percentile), medium (33rd–75th percentiles), or low (below the 33rd percentile).

Exploratory factor analysis reduced the indicators to two major themes. The first, which explains 28.3% of the variance, is related to product segmentation and market reach. The second, with 17.9%, captures aspects of the internal organization of the chain. Table 5 displays the

Varimax-rotated factor-pattern matrix, listing only the indicators with loadings ≥ 0.40 on the two latent factors and their final communalities (h^2).

Indicators	F1 – Product segmentation & market reach	F2 - Internal organization of the chain	h^2 (Final communality)
Production variation	**0.62**		0.87
Production cost efficiency	**0.76**		0.90
Feed substrate preparation efficiency		0.50	0.89
Larva-waste separation efficiency		**0.71**	0.85
Slaughter process efficiency		**0.84**	0.83
Efficiency in the Transformation into Final Products		**0.95**	0.95
Residual biomass utilization rate		**0.71**	0.81
Commercial utilization of frass		**0.81**	0.92
Logistics efficiency	**0.74**		0.88
Training program effectiveness		**0.72**	0.92
Gender diversity and equity in the workforce	0.41	**0.73**	0.71
Adaptation to diversified markets	0.54		0.76
Effectiveness of market segmentation	**0.86**		0.98
Regional expansion efficiency	**0.81**		0.94
Customer growth and retention	**0.77**		0.75
Revenue from exports		**-0.62**	0.85
Accuracy of Price Forecasting	**0.77**		0.92
Competitive advantage in the market	**0.81**		0.89
Adaptability to regulatory changes	**0.51**		0.62
Customer base diversification	**0.87**		0.86
Sales to strategic clients	**0.75**		0.98
Effectiveness of marketing and sales strategies	**0.60**		0.77
Diversification of sales channels	**0.83**		0.83
Supplier base diversification	**0.53**		0.93
Quality of supplier relationships	**0.87**		0.96
Variance explained (%)	28.3	17.9	
Cumulative (%)	28.3	46.2	
KMO	0.59		

Table 5 – Rotated factorial pattern matrix (PAF, Varimax, n = 17)

Note: Only loadings ≥ 0.40 are displayed; boldface indicates, for each variable, the factor with the highest cos^2

Source: Research data (2025)

As Table 5 illustrates, Factor 1 clusters indicators of market positioning, whereas Factor 2 groups items linked to internal operational routines. This loading structure substantiates the chosen factor labels and shows that the two dimensions, taken together, explain nearly half of the common variance in the dataset.

Six indicators, which combine high centrality with robust factor loadings (≥ 0.70), highlight their strategic weight in the system; these appear in Table 5.

Indicator	Centrality (%)	Dominant Factor	Factor Loading	Classification
Quality of Supplier Relationships	42.1	Factor 1	0.87	high centrality + high loading
Effectiveness of Market Segmentation	36.8	Factor 1	0.86	high centrality + high loading
Accuracy of Price Forecasting	31.6	Factor 1	0.77	high centrality + high loading
Competitive Advantage in the Market	31.6	Factor 1	0.81	high centrality + high loading
Efficiency in the Transformation into Final Products	26.3	Factor 2	0.95	high centrality + high loading
Production Cost Efficiency	26.3	Factor 1	0.76	high centrality + high loading

Table 5 – Indicators with High Connectivity and Factor Relevance
Note: “Factor loading” indicates the weight of an indicator within a statistical dimension; “centrality” refers to the percentage of significant connections with other indicators.
Source: Research data (2025)

Although production cost efficiency met the statistical threshold, three of its five significant links overlapped with other top-tier indicators. Those inter-primary correlations were omitted from Table 6 to keep each analytic axis distinct, allowing the spotlight to remain on connections with supporting variables and preventing circular interpretations.

4.3 Detailed analysis of the leading indicators and their interrelationships

Table 6 concentrates on the five indicators that surfaced as the chain’s main pivot points—Quality of Supplier Relationships, Effectiveness of Market Segmentation, Accuracy of Price Forecasting, Competitive Advantage in the Market, and efficiency in the transformation into final products—showing how each connects to supporting variables at different stages of the chain.

Key Perfomance Indicator	Correlated Indicators	Value Chain Stage	Correlation Coefficient (r)
Quality of Supplier Relationships	Customer base diversification	Commercial risk and dependency	0.81
	Customer growth and retention	Customer growth	0.76
	Production cost efficiency	Production and cost efficiency	0.75
	Diversification of sales channels	Sales strategies and channels	0.74
	Production variation	Production and cost efficiency	0.71
Effectiveness of Market Segmentation	Regional expansion efficiency	Regional expansion	0.90
	Logistics efficiency	Distribution and logistics	0.74
	Customer growth and retention	Customer growth	0.73
	Production cost efficiency	Production and cost efficiency	0.73
Accuracy of Price Forecasting	Production variation	Production and cost efficiency	0.81
	Regional expansion efficiency	Regional expansion	0.76
	Production cost efficiency	Production and cost efficiency	0.71
Competitive Advantage in the Market	Diversification of sales channels	Sales strategies and channels	0.76
	Customer growth and retention	Customer growth	0.70
	Effectiveness of marketing and sales strategies	Sales strategies and channels	0.71
Efficiency in the transformation into final products	Slaughter process efficiency	Processing and packaging	0.90
	Larva-waste separation efficiency	Processing and packaging	0.75
	Gender diversity and equity in the workforce	Workforce and diversity	0.73
	Residual biomass utilization rate	By-product utilization	0.72
	Training program effectiveness	Training and development	0.71

Table 6 – Interconnectivity of Core Indicators and Affected Value Chain Stages

Note: The closer to 1, the stronger the correlation between indicators.

Source: Research data (2025)

Main Findings:

- Quality of Supplier Relationships: Strong, well-managed links with input providers ripple through five other variables. Reliable supply lowers production costs, steadies output, fosters customer loyalty and broadens sales channels.
- Effectiveness of Market Segmentation: Pinpointing the right niches boosts territorial reach, tightens logistics, enlarges the client base, and keeps costs in check. Scale, in this context, flows from knowing exactly whom to serve.
- Accuracy of Price Forecasting: Firms that read the market accurately plan output more confidently, expand geographically with less risk, and trim expenses—an edge when prices swing unpredictably.
- Competitive Advantage in the Market: This indicator aligns less with intrinsic product traits and more with how the offer is positioned and promoted: choice of sales channels, retention tactics, and marketing mix all matter.
- Efficiency in the Transformation into Final Products: Five solid links place this metric at the heart of internal operations, from processing technique to workforce skills and training.

Strategic Implications:

- Long-term supplier programs—including qualification schemes and joint purchasing—can shore up resilience and cut costs.
- Mapping promising segments and adapting products and channels in a segmented manner can drive sustainable growth and reduce logistical inefficiencies.
- Market monitoring systems and predictive tools can improve decision-making accuracy and reduce risks.
- Integrated branding, marketing, and customer experience strategies are fundamental for positioning in an emerging sector.
- Full use of biomass, robust processing protocols, and ongoing staff training lift productivity and add value.

The analysis underscores the chain's tightly knit nature: moving in one area quickly echoes elsewhere. Treating these indicators as a connected management toolkit can help entrepreneurs and policymakers build a leaner, greener, and more competitive sector, furthering edible insects' case as a credible answer to food security and environmental challenges.

5. DISCUSSION

This section links the results to existing research on value-chain dynamics and the edible insect industry, showing how the findings add theoretical insight and practical guidance for Brazil and other emerging economies.

5.1 Summary of key findings

Brazil's insect business still resembles many young industries: the landscape is dominated by micro- and small enterprises, and production concentrates on Hermetia illucens and Tenebrio molitor. These two species, praised for their biological efficiency and nutritional quality (Veldkamp et al., 2012; Rumpold & Schlüter, 2013a), have found a natural niche in animal feed and pet food markets. They also tick the circular economy box by converting organic residues into protein-rich biomass (Sun-Waterhouse et al., 2016; Cortes Ortiz et al., 2016).

Five indicators—quality of Supplier Relationships, Effectiveness of Market Segmentation, Accuracy of Price Forecasting, Competitive Advantage in the Market, and Efficiency in the Transformation into Final Products—emerged as the sector's principal levers. The first four showed dense networks of significant links that spanned every analytical dimension; the fifth exerted a more focused influence on internal operations such as training and workforce diversity.

- Quality of Supplier Relationships. A reliable pipeline of organic inputs translates into steadier production, lower costs, and a broader customer base. High factor loading (0.87) and solid correlation with production cost efficiency ($r = 0.75$) confirm the strategic value of long-term partnerships (Bermúdez-Serrano, 2020).
- Effectiveness of Market Segmentation. Pinpointing the right customer groups supports territorial expansion, leaner logistics, and higher retention rates. A factor loading (0.86)—and a powerful tie to regional expansion efficiency ($r = 0.90$)—echo findings by Hartmann et al. (2015) and Li et al. (2023), who view segmentation as a key response to cultural barriers in Western markets.
- Accuracy of Price Forecasting. Producers that anticipate price swings can trim or boost output quickly, buffering financial shocks. Its correlation with production adjustment ($r = 0.77$) reinforces earlier work on adaptive planning and the cost of environmental control (Cortes Ortiz et al., 2016; Oonincx & De Boer, 2012).
- Competitive Advantage in the Market. The data suggest that, for now, differentiation rests more on channel mix, branding, and customer experience than on novel product features. This pattern aligns with recent market reports (Mordor Intelligence, 2024; Fortune Business Insights, 2025) and studies that stress the role of clear nutritional messaging and sensory improvements (Li et al., 2023; Rumpold & Schlüter, 2013a).

- Efficiency in the Transformation into Final Products. Strong links with slaughter practices (r = 0.90), larva–waste separation (r = 0.75), and residual-biomass use (r = 0.72) show that technical tweaks can lift both yield and sustainability (Costa et al., 2021; Spykman et al., 2021; IPFF, 2022). Associations with training quality (r = 0.71) and gender diversity (r = 0.73) hint that skilled, inclusive teams may drive additional gains—an avenue worth probing further.

The indicators work together like meshing gears—touch one, and the rest tend to shift. Viewing them as a single dashboard lets entrepreneurs and policymakers nudge the industry toward higher efficiency, greater resilience, and stronger sustainability, bolstering the argument for insects as a real solution to food security and environmental pressures.

5.2 Practical implications and managerial contributions

The study delivers a validated dashboard of five indicators well suited to day-to-day decision-making in Brazil's young insect sector, where the same firm often handles more than one stage of the chain.

Quality of Supplier Relationships. Biofactories can raise performance by tightening partner-selection rules, negotiating longer-term contracts, and tracking supplier metrics in real time. A stronger upstream network steadies' production, trims costs, and lets firms react more quickly to market shifts echoing Van Huis (2013) and Johnsen (2009), who link collaborative supply models to sustainable growth.

Effectiveness of Market Segmentation. Regularly mapping consumer niches helps processors and sellers tailor products, price points, and logistics to local realities. Better alignment between demand and distribution cuts transport slack and speeds market take-off, an approach Hartmann et al. (2015) and Li et al. (2023) see as crucial for overcoming cultural resistance.

Accuracy of Price Forecasting. Reliable cost and revenue forecasts guard margins when energy or substrate prices swing. By closely watching price signals, firms can adjust batch size, avoid over-production, and steady cash flow. Veldkamp et al. (2012) and Spykman et al. (2021) reach the same conclusion, stressing the need for robust predictive models in a cost-sensitive industry.

Competitive Advantage in the Market. Tracking these metric steers branding, channel mix, and retention initiatives. Clear nutritional messaging, assertive digital outreach, and varied sales outlets distinguish early movers—a point underlined by recent market reviews (Mordor Intelligence, 2024; Fortune Business Insights, 2025).

Efficiency in the Transformation into Final Products. Fine-tuning slaughter, separation, and by-product recovery boosts yield while closing resource loops—frass, for instance, can be sold as fertilizer (Spykman et al., 2021). Field data also hint at the value of inclusive teams: women often excel in breeding and larval care, and broader gender balance could drive further gains.

Because many biofactories are in rural or peri-urban zones, they create local jobs and weave themselves into the social fabric. Promoting diversity, skills training, and career paths turns these plants into hubs of community resilience.

In short, using this indicator set allows managers, investors, and policymakers to spot bottlenecks and craft forward-looking strategies—even amid regulatory grey areas and rapid technological change. For Brazilian firms that straddle several stages of the chain, the framework offers a concrete edge: sharper efficiency, greater agility, and more sustainable growth.

5.3 Study contributions

The empirical evidence confirms the focal species' technical and nutritional merits (see Table 2; Veldkamp et al., 2012): when supported by proper production and marketing practices, these insects can serve as high-value ingredients in both feed and food. This result echoes Rumpold and Schlüter's (2013a) argument that insects function well as components of balanced human and animal diets.

This research's distinctive contribution is a quantitative framework explicitly designed for Brazil's young insect industry. It weaves together operational measures and market-oriented variables, organized according to the stages in the Handbook for Value Chain Research. The study reveals which factors significantly influence sector performance by applying correlation and exploratory factor analysis.

For practitioners, the indicator set functions like an off-the-shelf guide. Owners and managers can use it to decide which tasks deserve attention first, where new funds are most justified, and how to monitor progress as the business grows. At the policy level, the same metrics make it easier to spot the value-chain points where targeted rules or incentives would do the best. In short, the indicators give everyone involved a concrete place to start when strengthening novel, sustainability-driven protein pathways.

5.4 Study limitations

The first constraint lies in the sample: the survey covered a young industry still dominated by micro and small-scale firms. Findings, therefore, mirror the sector's early Brazilian landscape and may not transfer directly to larger, export-oriented companies. Because the study remains Brazil-centred, it cannot be compared with more mature chains in the European Union or Asia—comparisons that might have revealed additional growth paths and best practices.

A second limitation is regulatory. Brazil still lacks specific rules for insects intended for human food. Although progress has been made on feed applications, this grey zone hampers formal registration, process standardization, and the roll-out of structured management systems. Uncertainty can shape how producers interpret and report the key performance indicators, add extra costs, and complicate strategic choices.

Methodologically, the research relies on self-reported Likert-scale data, which carries an inherent risk of subjectivity and varied interpretation. Steps were taken to reduce such bias—the questionnaire had been validated earlier, and correlation analysis added a cross-check—but respondents' perceptions may still diverge from on-the-ground realities.

Regarding value-chain analysis, Kaplinsky and Morris (2001) note that no blueprint fits every case; tools must be chosen to match the context. Three factors limited the present study's ability to apply the complete set of instruments from the Handbook for Value Chain Research:

(i) Limited access to strategic in-house data, which blocked deeper dives into governance and benchmarking.

(ii) a focus on numbers we could measure, leaving less room for qualitative issues such as power dynamics and.

(iii) Time and resource constraints ruled out a more extensive methodological roll-out.

Therefore, the selective use of the framework was an adaptation to an emerging sector where data remain scarce. The study identified indicators well suited to Brazil's current context, even within these bounds.

Future research should build on the following directions:

- Longitudinal research to chart how the chain evolves and where structural shifts occur.
- Methodological triangulation mixes in-depth interviews or field observation with quantitative surveys to capture contextual nuance.
- International comparisons to position Brazil alongside more developed value chains and distill transferable lessons.

Pursuing these paths would deepen understanding, refine the methodological toolbox for Brazil's edible insect industry, and help weave the sector into broader sustainability agendas.

6. FINAL CONSIDERATIONS

Using the framework in the Handbook for Value Chain Research and a mixed-methods design, the study created and tested key performance indicators specific to Brazil's still-emerging edible insect chain. The work pinpoints factors that drive efficiency, competitiveness, and sustainability, offering insights that speak to academics and industry practitioners alike.

Findings confirm that the chain remains emergent. Production centers mainly on Hermetia illucens and Tenebrio molitor, and most output is channeled into animal-feed ingredients—a market-entry strategy grounded in circular economy thinking and the conversion of organic waste.

Integrated statistical tests highlighted five indicators: Quality of Supplier Relationships, Effectiveness of Market Segmentation, Accuracy of Price Forecasting, Competitive Advantage in the Market, and Efficiency in the Transformation into Final Products. Each combined high centrality in the correlation network with strong factor loadings, underscoring a pivotal role across operational and market domains.

Managerial implications:

- Building long-term alliances with input suppliers stabilizes production, cuts costs, and boosts resilience.
- Fine-grained market segmentation clarifies consumer diversity and helps tailor logistics, pricing, and product formats.
- Reliable price-forecast tools support agile adjustments to volume and budget, guarding margins when input costs swing.
- Coordinated branding and channel strategies to foster acceptance in a market still earning public trust.
- Process optimization - especially in slaughter, separation, and by-product recovery—raises yield while reinforcing circular economy credentials.

Policy implications:

Clear regulations, accessible credit lines, and technical extension programs would lower entry barriers and speed formalization. Field observations also highlight the value of inclusive workforce policies; women already play key roles in breeding and rearing, and broader participation could strengthen social impact and operational performance.

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Appendix A - Questionnaire

P1. What is the size of your business?

P2. What is the main focus of your business's production?

P3. Which insect species do you currently produce?

P4. How do you commercialize the insects you produce?

P5. If you produce animal feed, which are the main segments you serve?

P6. How do you assess the increase in total production over the past 12 months?

P7. What efficiency level was achieved in total production cost over the past 12 months?

P8. What is the difficulty level in acquiring raw materials used to feed production?

P9. How do you evaluate the efficiency of reproductive management in your production?

P10. How do you assess the efficiency of preparing the feeding substrate used in production?

P11. How do you evaluate the effectiveness of rearing newly hatched larvae?

P12. What is the level of efficiency in climate control in the production units?

P13. How do you evaluate the effectiveness of sanitary management in your production?

P14. What is the level of efficiency in the process of separating larvae from the generated waste?

P15. How do you classify the effectiveness of the harvesting/slaughtering process within the production cycle?

P16. What is the level of efficiency in transforming production into final products?

P17. What is the level of sustainability of the packaging used for delivering the final products?

P18. To what extent is residual biomass being utilized for specific purposes?

P19. To what extent has your business been able to explore the commercial potential of frass?

P20. How do you evaluate the efficiency of the means used to deliver products to customers?

P21. How do specialized services, such as technical consultancy, impact product efficiency and quality?

P22. How do you assess the effectiveness of training programs for your employees and partners in developing skills and innovation?

P23. What is the level of diversity and gender balance among your staff?

P24. How do you assess your business's capacity to meet needs and explore opportunities in different types of markets?

P25. How do you assess the distribution of sales across different types of customers?

P26. How do you evaluate the effectiveness of selling your products in different regions?

P27. How well has your business expanded and maintained active customers over the past 12 months?

P28. How do you assess the contribution of exports to your business's total revenue?

P29. How do you assess the balance between the use of foreign and domestic suppliers for inputs and raw materials?

P30. How do you evaluate your business's ability to forecast and manage changes in market prices?

P31. How well does your business stand out from its direct competitors?

P32. How do you assess your business's resilience to government regulations and policies that affect the market?

P33. What is the level of diversification in your buyer base across different market types?

P34. To what extent do strategic buyers represent a significant share of your business's total sales?

P35. How effective are your marketing and sales strategies in reaching different types of buyers?

P36. How do you assess the balance in sales distribution across different delivery methods or channels?

P37. What is the level of diversification among the suppliers from whom you obtain necessary materials and resources?

P38. Considering the length and quality of communication, how strong is your business's relationship with key suppliers?

Appendix B - Correlation matrix (Spearman)

Correlation matrix (Spearman):	Production variation	Production cost efficiency	Raw material accessibility	Reproductive management efficiency	Feed substrate preparation efficiency	Initial larval survival	Climate stability in production units	Production sanitary control
Production variation	**1**	0,812	0,043	0,383	0,240	0,572	0,614	0,174
Production cost efficiency	0,812	**1**	0,116	0,200	0,197	0,344	0,398	0,250
Raw material accessibility	0,043	0,116	**1**	-0,413	-0,374	0,219	-0,300	0,120
Reproductive management efficiency	0,383	0,200	-0,413	**1**	0,462	0,238	0,242	-0,340
Feed substrate preparation efficiency	0,240	0,197	-0,374	0,462	**1**	-0,239	0,445	0,034
Initial larval survival	0,572	0,344	0,219	0,238	-0,239	**1**	0,357	0,261
Climate stability in production units	0,614	0,398	-0,300	0,242	0,445	0,357	**1**	0,388
Production sanitary control	0,174	0,250	0,120	-0,340	0,034	0,261	0,388	**1**
Larva-waste separation efficiency	0,523	0,253	0,223	0,321	0,224	0,588	0,248	0,049
Slaughter process efficiency	0,406	0,137	0,146	0,228	0,404	0,289	0,236	0,302
Efficiency in the Transformation into Final Products	0,418	0,215	0,146	0,357	0,491	0,233	0,193	0,212
Packaging sustainability	0,440	0,371	-0,157	0,522	0,018	0,360	0,307	-0,179
Residual biomass utilization rate	0,204	0,162	0,124	0,247	0,235	0,244	0,162	0,179
Commercial utilization of frass	0,278	0,140	0,165	0,246	0,389	0,377	0,270	0,179
Logistics efficiency	0,493	0,604	0,272	0,210	0,160	0,208	0,080	0,270
Impact of specialized services	0,439	0,217	0,010	0,426	-0,104	0,660	0,220	-0,162
Training program effectiveness	0,433	0,121	-0,161	0,659	0,583	0,300	0,409	-0,026
Gender diversity and equity in the workforce	0,402	0,373	0,176	0,339	0,433	0,225	0,221	0,197
Adaptation to diversified markets	0,522	0,474	0,268	0,079	-0,347	0,504	0,082	0,265
Effectiveness of market segmentation	0,603	0,727	0,065	0,368	0,037	0,361	0,206	0,017
Regional expansion efficiency	0,602	0,739	0,157	0,359	0,140	0,330	0,008	-0,012
Customer growth and retention	0,580	0,671	-0,049	0,125	-0,039	0,236	0,355	0,177
Revenue from exports	0,212	0,342	-0,356	-0,021	-0,094	-0,143	0,232	-0,246
Domestic vs. imported input ratio	0,391	0,290	0,041	0,225	-0,071	0,178	0,304	-0,383
Accuracy of Price Forecasting	0,811	0,712	-0,106	0,530	0,130	0,535	0,499	0,085
Competitive advantage in the market	0,567	0,609	-0,088	0,427	0,305	0,179	0,435	0,173
Adaptability to regulatory changes	0,580	0,435	-0,165	0,549	0,591	0,064	0,500	0,054
Customer base diversification	0,495	0,579	0,320	0,120	0,103	0,192	0,174	0,345
Sales to strategic clients	0,290	0,337	0,198	0,189	-0,028	0,023	0,017	0,033
Effectiveness of marketing and sales strategies	0,610	0,534	-0,004	0,309	0,485	0,182	0,678	0,219
Diversification of sales channels	0,369	0,490	-0,003	0,166	0,052	0,236	0,353	0,445
Supplier base diversification	0,495	0,612	0,108	-0,012	0,157	0,026	0,107	0,145
Quality of supplier relationships	0,707	0,746	0,069	0,099	0,168	0,295	0,510	0,465

Correlation matrix (Spearman):	Training program effectiveness	Gender diversity and equity in the workforce	Adaptation to diversified markets	Effectiveness of market segmentation	Regional expansion efficiency	Customer growth and retention	Revenue from exports	Domestic vs. imported input ratio
Production variation	0,433	0,402	0,522	0,603	0,602	0,580	0,212	0,391
Production cost efficiency	0,121	0,373	0,474	0,727	0,739	0,671	0,342	0,290
Raw material accessibility	-0,161	0,176	0,268	0,065	0,157	-0,049	-0,356	0,041
Reproductive management efficiency	0,659	0,339	0,079	0,368	0,359	0,125	-0,021	0,225
Feed substrate preparation efficiency	0,583	0,433	-0,347	0,037	0,140	-0,039	-0,094	-0,071
Initial larval survival	0,300	0,225	0,504	0,361	0,330	0,236	-0,143	0,178
Climate stability in production units	0,409	0,221	0,082	0,206	0,008	0,355	0,232	0,304
Production sanitary control	-0,026	0,197	0,265	0,017	-0,012	0,177	-0,246	-0,383
Larva-waste separation efficiency	0,581	0,453	0,260	0,199	0,349	-0,091	-0,160	0,240
Slaughter process efficiency	0,744	0,719	0,283	0,123	0,280	0,099	-0,538	-0,130
Efficiency in the Transformation into Final Products	0,708	0,731	0,184	0,109	0,293	-0,087	-0,475	-0,055
Packaging sustainability	0,404	0,283	0,215	0,295	0,227	0,232	0,435	0,428
Residual biomass utilization rate	0,314	0,528	0,169	0,117	0,137	-0,296	-0,307	0,091
Commercial utilization of frass	0,532	0,642	0,272	0,279	0,318	-0,061	-0,554	-0,003
Logistics efficiency	0,290	0,517	0,718	0,739	0,745	0,617	-0,182	0,118
Impact of specialized services	0,411	-0,009	0,603	0,437	0,375	0,352	0,122	0,329
Training program effectiveness	**1**	0,577	0,160	0,178	0,273	0,131	-0,226	0,100
Gender diversity and equity in the workforce	0,577	**1**	0,190	0,416	0,489	0,268	-0,340	-0,050
Adaptation to diversified markets	0,160	0,190	**1**	0,650	0,571	0,577	0,051	0,283
Effectiveness of market segmentation	0,178	0,416	0,650	**1**	0,900	0,734	0,284	0,527
Regional expansion efficiency	0,273	0,489	0,571	0,900	**1**	0,586	0,125	0,306
Customer growth and retention	0,131	0,268	0,577	0,734	0,586	**1**	0,486	0,347
Revenue from exports	-0,226	-0,340	0,051	0,284	0,125	0,486	**1**	0,556
Domestic vs. imported input ratio	0,100	-0,050	0,283	0,527	0,306	0,347	0,556	**1**
Accuracy of Price Forecasting	0,333	0,378	0,612	0,882	0,759	0,680	0,226	0,504
Competitive advantage in the market	0,370	0,501	0,416	0,791	0,650	0,757	0,233	0,477
Adaptability to regulatory changes	0,458	0,348	0,221	0,531	0,513	0,255	0,001	0,276
Customer base diversification	0,151	0,583	0,407	0,681	0,692	0,540	-0,109	0,090
Sales to strategic clients	0,152	0,126	0,276	0,547	0,528	0,480	0,221	0,471
Effectiveness of marketing and sales strategies	0,381	0,509	0,095	0,461	0,316	0,479	0,051	0,428
Diversification of sales channels	0,103	0,260	0,386	0,699	0,556	0,627	0,115	0,280
Supplier base diversification	0,072	0,230	0,063	0,283	0,468	0,278	0,319	0,083
Quality of supplier relationships	0,062	0,427	0,471	0,710	0,603	0,759	0,160	0,190

Correlation matrix (Spearman):	Larva-waste separation efficiency	Slaughter process efficiency	Efficiency in the Transformation into Final Products	Packaging sustainability	Residual biomass utilization rate	Commercial utilization of frass	Logistics efficiency	Impact of specialized services
Production variation	0,523	0,406	0,418	0,440	0,204	0,278	0,493	0,439
Production cost efficiency	0,253	0,137	0,215	0,371	0,162	0,140	0,604	0,217
Raw material accessibility	0,223	0,146	0,146	-0,157	0,124	0,165	0,272	0,010
Reproductive management efficiency	0,321	0,228	0,357	0,522	0,247	0,246	0,210	0,426
Feed substrate preparation efficiency	0,224	0,404	0,491	0,018	0,235	0,389	0,160	-0,104
Initial larval survival	0,588	0,289	0,233	0,360	0,244	0,377	0,208	0,660
Climate stability in production units	0,248	0,236	0,193	0,307	0,162	0,270	0,080	0,220
Production sanitary control	0,049	0,302	0,212	-0,179	0,179	0,179	0,270	-0,162
Larva-waste separation efficiency	**1**	0,598	0,746	0,481	0,665	0,579	0,155	0,368
Slaughter process efficiency	0,598	**1**	0,897	0,040	0,441	0,698	0,493	0,090
Efficiency in the Transformation into Final Products	0,746	0,897	**1**	0,263	0,717	0,678	0,393	-0,011
Packaging sustainability	0,481	0,040	0,263	**1**	0,435	-0,010	-0,066	0,312
Residual biomass utilization rate	0,665	0,441	0,717	0,435	**1**	0,654	0,167	-0,043
Commercial utilization of frass	0,579	0,698	0,678	-0,010	0,654	**1**	0,496	0,274
Logistics efficiency	0,155	0,493	0,393	-0,066	0,167	0,496	**1**	0,313
Impact of specialized services	0,368	0,090	-0,011	0,312	-0,043	0,274	0,313	**1**
Training program effectiveness	0,581	0,744	0,708	0,404	0,314	0,532	0,290	0,411
Gender diversity and equity in the workforce	0,453	0,719	0,731	0,283	0,528	0,642	0,517	-0,009
Adaptation to diversified markets	0,260	0,283	0,184	0,215	0,169	0,272	0,718	0,603
Effectiveness of market segmentation	0,199	0,123	0,109	0,295	0,117	0,279	0,739	0,437
Regional expansion efficiency	0,349	0,280	0,293	0,227	0,137	0,318	0,745	0,375
Customer growth and retention	-0,091	0,099	-0,087	0,232	-0,296	-0,061	0,617	0,352
Revenue from exports	-0,160	-0,538	-0,475	0,435	-0,307	-0,554	-0,182	0,122
Domestic vs. imported input ratio	0,240	-0,130	-0,055	0,428	0,091	-0,003	0,118	0,329
Accuracy of Price Forecasting	0,292	0,220	0,186	0,359	0,122	0,299	0,612	0,522
Competitive advantage in the market	0,178	0,347	0,305	0,272	0,115	0,255	0,694	0,171
Adaptability to regulatory changes	0,285	0,304	0,353	0,095	0,208	0,399	0,470	0,228
Customer base diversification	0,050	0,303	0,226	-0,008	0,011	0,184	0,637	-0,001
Sales to strategic clients	0,042	0,098	0,073	0,124	-0,201	-0,224	0,387	0,001
Effectiveness of marketing and sales strategies	0,118	0,367	0,336	0,148	0,124	0,266	0,417	-0,016
Diversification of sales channels	-0,097	0,106	-0,006	0,017	-0,115	0,039	0,537	0,073
Supplier base diversification	0,157	0,060	0,163	0,287	-0,047	-0,284	0,086	-0,181
Quality of supplier relationships	0,030	0,221	0,112	0,010	-0,052	0,159	0,649	0,132

Correlation matrix (Spearman):	Accuracy of Price Forecasting	Competitive advantage in the market	Adaptability to regulatory changes	Customer base diversification	Sales to strategic clients	Effectiveness of marketing and sales strategies	Diversification of sales channels	Supplier base diversification	Quality of supplier relationships
Production variation	0,811	0,567	0,580	0,495	0,290	0,610	0,369	0,495	0,707
Production cost efficiency	0,712	0,609	0,435	0,579	0,337	0,534	0,490	0,612	0,746
Raw material accessibility	-0,106	-0,088	-0,165	0,320	0,198	-0,004	-0,003	0,108	0,069
Reproductive management efficiency	0,530	0,427	0,549	0,120	0,189	0,309	0,166	-0,012	0,099
Feed substrate preparation efficiency	0,130	0,305	0,591	0,103	-0,028	0,485	0,052	0,157	0,168
Initial larval survival	0,535	0,179	0,064	0,192	0,023	0,182	0,236	0,026	0,295
Climate stability in production units	0,499	0,435	0,500	0,174	0,017	0,678	0,353	0,107	0,510
Production sanitary control	0,085	0,173	0,054	0,345	0,033	0,219	0,445	0,145	0,465
Larva-waste separation efficiency	0,292	0,178	0,285	0,050	0,042	0,118	-0,097	0,157	0,030
Slaughter process efficiency	0,220	0,347	0,304	0,303	0,098	0,367	0,106	0,060	0,221
Efficiency in the Transformation into Final Products	0,186	0,305	0,353	0,226	0,073	0,336	-0,006	0,163	0,112
Packaging sustainability	0,359	0,272	0,095	-0,008	0,124	0,148	0,017	0,287	0,010
Residual biomass utilization rate	0,122	0,115	0,208	0,011	-0,201	0,124	-0,115	-0,047	-0,052
Commercial utilization of frass	0,299	0,255	0,399	0,184	-0,224	0,266	0,039	-0,284	0,159
Logistics efficiency	0,612	0,694	0,470	0,637	0,387	0,417	0,537	0,086	0,649
Impact of specialized services	0,522	0,171	0,228	-0,001	0,001	-0,016	0,073	-0,181	0,132
Training program effectiveness	0,333	0,370	0,458	0,151	0,152	0,381	0,103	0,072	0,062
Gender diversity and equity in the workforce	0,378	0,501	0,348	0,583	0,126	0,509	0,260	0,230	0,427
Adaptation to diversified markets	0,612	0,416	0,221	0,407	0,276	0,095	0,386	0,063	0,471
Effectiveness of market segmentation	0,882	0,791	0,531	0,681	0,547	0,461	0,699	0,283	0,710
Regional expansion efficiency	0,759	0,650	0,513	0,692	0,528	0,316	0,556	0,468	0,603
Customer growth and retention	0,680	0,757	0,255	0,540	0,480	0,479	0,627	0,278	0,759
Revenue from exports	0,226	0,233	0,001	-0,109	0,221	0,051	0,115	0,319	0,160
Domestic vs. imported input ratio	0,504	0,477	0,276	0,090	0,471	0,428	0,280	0,083	0,190
Accuracy of Price Forecasting	**1**	0,750	0,689	0,644	0,457	0,586	0,675	0,287	0,776
Competitive advantage in the market	0,750	**1**	0,571	0,608	0,663	0,709	0,763	0,175	0,726
Adaptability to regulatory changes	0,689	0,571	**1**	0,544	0,354	0,508	0,459	0,216	0,570
Customer base diversification	0,644	0,608	0,544	**1**	0,623	0,551	0,770	0,538	0,810
Sales to strategic clients	0,457	0,663	0,354	0,623	**1**	0,424	0,745	0,448	0,436
Effectiveness of marketing and sales strategies	0,586	0,709	0,508	0,551	0,424	**1**	0,589	0,295	0,675
Diversification of sales channels	0,675	0,763	0,459	0,770	0,745	0,589	**1**	0,310	0,741
Supplier base diversification	0,287	0,175	0,216	0,538	0,448	0,295	0,310	**1**	0,402
Quality of supplier relationships	0,776	0,726	0,570	0,810	0,436	0,675	0,741	0,402	**1**

Appendix C – AFE – Varimax – KMO

Factor pattern after Varimax rotation:	D1	D2	D3	D4	D5
Production variation	**0,617**	0,281	0,202	0,359	0,375
Production cost efficiency	**0,764**	0,085	0,113	0,187	0,188
Raw material accessibility	0,170	0,164	-0,296	0,174	**-0,522**
Reproductive management efficiency	0,165	0,381	**0,594**	0,058	0,292
Feed substrate preparation efficiency	0,072	0,504	0,175	-0,479	**0,545**
Initial larval survival	0,202	0,257	-0,023	**0,751**	0,120
Climate stability in production units	0,229	0,121	-0,007	0,171	**0,918**
Production sanitary control	0,251	0,137	**-0,675**	0,063	0,243
Larva-waste separation efficiency	0,037	**0,709**	0,292	0,380	0,013
Slaughter process efficiency	0,189	**0,844**	-0,167	0,038	0,088
Efficiency in the Transformation into Final Products	0,121	**0,949**	0,049	-0,041	0,038
Packaging sustainability	0,115	0,166	**0,639**	0,284	0,161
Residual biomass utilization rate	-0,074	**0,712**	0,098	0,158	0,011
Commercial utilization of frass	0,065	**0,813**	-0,175	0,281	0,124
Logistics efficiency	**0,736**	0,359	-0,191	0,204	-0,095
Impact of specialized services	0,135	0,067	0,289	**0,803**	0,109
Training program effectiveness	0,107	**0,717**	0,333	0,067	0,323
Gender diversity and equity in the workforce	0,407	**0,727**	-0,031	-0,072	0,065
Adaptation to diversified markets	0,539	0,112	-0,072	**0,650**	-0,157
Effectiveness of market segmentation	**0,864**	0,071	0,241	0,301	-0,012
Regional expansion efficiency	**0,809**	0,261	0,243	0,182	-0,198
Customer growth and retention	**0,774**	-0,207	0,047	0,233	0,208
Revenue from exports	0,225	**-0,623**	0,525	0,055	0,227
Domestic vs. imported input ratio	0,357	-0,146	**0,586**	0,250	0,100
Accuracy of Price Forecasting	**0,773**	0,130	0,238	0,374	0,308
Competitive advantage in the market	**0,806**	0,184	0,172	0,002	0,277
Adaptability to regulatory changes	**0,510**	0,341	0,191	-0,073	0,378
Customer base diversification	**0,870**	0,189	-0,198	-0,112	-0,054
Sales to strategic clients	**0,750**	-0,077	0,240	-0,213	-0,189
Effectiveness of marketing and sales strategies	**0,597**	0,240	0,023	-0,150	0,508
Diversification of sales channels	**0,826**	-0,076	-0,139	-0,032	0,184
Supplier base diversification	**0,531**	-0,003	0,193	-0,281	-0,047
Quality of supplier relationships	**0,868**	0,010	-0,251	0,087	0,341

Values in bold correspond for each variable to the factor for which the squared cosine is the largest

Percentage of variance after Varimax rotation:	D1	D2	D3	D4	D5
Variability (%)	28,377	17,911	8,665	9,181	8,668
Cumulative %	28,377	46,288	54,953	64,133	72,801

Kaiser-Meyer-Olkin measure of sampling adequacy (KMO)	
Production variation	0,710
Production cost efficiency	0,577
Raw material accessibility	0,373
Reproductive management efficiency	0,567
Feed substrate preparation efficiency	0,355
Initial larval survival	0,713
Climate stability in production units	0,405
Production sanitary control	0,323
Larva-waste separation efficiency	0,543
Slaughter process efficiency	0,619
Efficiency in the Transformation into Final Products	0,636
Packaging sustainability	0,429
Residual biomass utilization rate	0,498
Commercial utilization of frass	0,437
Logistics efficiency	0,787
Impact of specialized services	0,357
Training program effectiveness	0,545
Gender diversity and equity in the workforce	0,598
Adaptation to diversified markets	0,571
Effectiveness of market segmentation	0,734
Regional expansion efficiency	0,762
Customer growth and retention	0,674
Revenue from exports	0,478
Domestic vs. imported input ratio	0,500
Accuracy of Price Forecasting	0,782
Competitive advantage in the market	0,711
Adaptability to regulatory changes	0,655
Customer base diversification	0,765
Sales to strategic clients	0,742
Effectiveness of marketing and sales strategies	0,587
Diversification of sales channels	0,636
Supplier base diversification	0,496
Quality of supplier relationships	0,573
KMO	0,595

APÊNDICE E - Parecer Consubstanciado do CEP

UNIVERSIDADE PAULISTA - UNIP

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: CADEIA DE VALOR DO SISTEMA PRODUTIVO DE INSETOS COMESTÍVEIS COMO FONTE PROTEICA ALTERNATIVA: CONTRIBUIÇÃO NOS DESAFIOS DE DESENVOLVIMENTO SUSTENTÁVEL NO BRASIL

Pesquisador: JAQUELINE GEISA CUNHA GOMES

Área Temática:

Versão: 1

CAAE: 84211924.2.0000.5512

Instituição Proponente: ASSOCIACAO UNIFICADA PAULISTA DE ENSINO RENOVADO OBJETIVO-

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 7.255.655

Apresentação do Projeto:

Adequada. O projeto propõe analisar a cadeia de valor dos insetos comestíveis como fonte sustentável de proteína no Brasil.

Objetivo da Pesquisa:

Investigar o alinhamento da cadeia de valor com os princípios de sustentabilidade e ecoinovação, por meio do desenvolvimento e avaliação de indicadores de desempenho.

Avaliação dos Riscos e Benefícios:

não há

Comentários e Considerações sobre a Pesquisa:

O projeto não fere princípios éticos, se baseia em revisão bibliográfica e entrevistas semiestruturadas online com duas empresas especialistas na área (anexos: ¿frm_carta_anuencia_Agrin_assinado¿ e ¿frm_carta_anuencia_Lets¿Fly_assinada¿).

Considerações sobre os Termos de apresentação obrigatória:

adequado

Recomendações:

não há

Endereço: Rua Dr. Bacelar, 1212 4º andar
Bairro: Vila Clementino **CEP:** 04.026-002
UF: SP **Município:** SAO PAULO
Telefone: (11)5586-4086 **E-mail:** cep@unip.br

Conclusões ou Pendências e Lista de Inadequações:

adequado

Considerações Finais a critério do CEP:

Diante do exposto, o CEP-UNIP, de acordo com as atribuições definidas na Resolução CNS n.° 466, de 2012, manifesta-se por confirmar o parecer do projeto de pesquisa como APROVADO, nos termos em que está proposto. Ressalta-se que cabe ao pesquisador responsável encaminhar os relatórios parciais e finais da pesquisa, por meio da Plataforma Brasil, via notificação do tipo ¿relatório¿ para que sejam devidamente apreciadas pelo CEP, conforme Norma Operacional CNS nr 001/12, item XI.2.d.

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_2411173.pdf	23/10/2024 17:35:24		Aceito
Projeto Detalhado / Brochura Investigador	Projeto_de_Pesquisa_JaquelineGomes.docx	23/10/2024 09:22:33	JAQUELINE GEISA CUNHA GOMES	Aceito
Outros	carta_de_apresentacao_do_projeto_de_pesquisa_assinado.pdf	23/10/2024 09:21:42	JAQUELINE GEISA CUNHA GOMES	Aceito
Folha de Rosto	folhaDeRosto_Assinatura.pdf	23/10/2024 09:17:24	JAQUELINE GEISA CUNHA GOMES	Aceito
Outros	Capa_do_Projeto_de_Pesquisa.docx	21/10/2024 12:46:25	JAQUELINE GEISA CUNHA GOMES	Aceito
Cronograma	Cronograma.xlsx	21/10/2024 12:44:24	JAQUELINE GEISA CUNHA GOMES	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	frm_termo_de_consentimento_TCLE_questionario.docx	21/10/2024 12:41:20	JAQUELINE GEISA CUNHA GOMES	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	frm_termo_de_consentimento_TCLE_entrevista.docx	21/10/2024 12:39:56	JAQUELINE GEISA CUNHA GOMES	Aceito
Orçamento	frm_orcamento_de_projeto_de_pesquisa.pdf	21/10/2024 12:38:04	JAQUELINE GEISA CUNHA GOMES	Aceito
Declaração de concordância	frm_carta_anuencia_Agrin_LetsFly_Asbracia.pdf	21/10/2024 12:37:23	JAQUELINE GEISA CUNHA GOMES	Aceito
Declaração de Pesquisadores	modelo2_termo_de_compromisso_do_pesquisador.pdf	21/10/2024 12:29:28	JAQUELINE GEISA CUNHA GOMES	Aceito

Situação do Parecer:
Aprovado

Necessita Apreciação da CONEP:
Não

SAO PAULO, 28 de Novembro de 2024

Assinado por:
Vânia Cristina Lamônica
(Coordenador(a))

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