integrating insects into the diets of a wide range of consumers through the creation of insect-based products is needed [25].

Finally, for the technological-environmental factor, Peru contributes 0.12% of GDP each year to technological development to promote research and development (R&D) [26], which should be oriented to improve productivity, diversify production, and add value to productive activities and services through the program Innóvate Perú [27]. Thus, it is necessary to disseminate these initiatives and, consequently, to enhance training capabilities according to market needs. In parallel, it is mentioned that a 10% increase in broadband penetration in industrial sectors is associated with a 1.4% growth in productivity for companies [28]. This increased investment in machinery and equipment seeks lower energy consumption and environmental prevention. Figure 1 below schematically presents the diagnosis of the *Acheta domestic* flour market explained above.

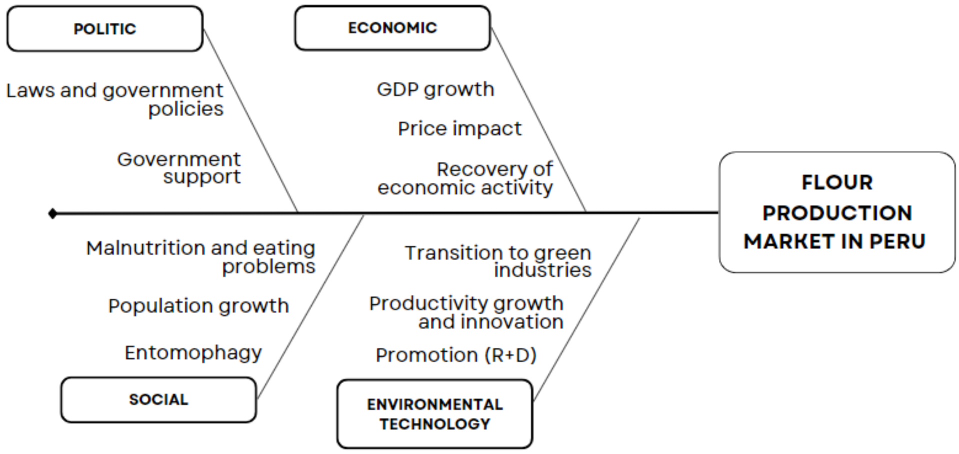

Fig. 1 PEST analysis of the Peruvian flour production market

C. Other Global Studies on Acheta Domesticus

As stated by various authors, edible insects have been identified as the food of the future mainly because of the significant advantages they possess as a food source [6], which makes them an efficient solution to establish new paths in the search for alternative nutritional sources along with sustainable practices [29]. This statement is supported by researchers who propose edible insects as a nutritional alternative to conventional products such as meat because they are a good source of protein, fats, and minerals; protein is the main component of these species [16]. However, the nutritional composition may vary depending on the family of insects and even within the group of the same species [30].

The insect family Gryllidae is considered nutritionally valuable due to the significant content of protein, fats, vitamins, and minerals [12]. Within this family, made up of insects colloquially known as crickets, the *Acheta domesticus* stands out, given that it has a protein content between 62.41% and 71.09% per 100 grams of dry weight [2] which gives them an advantage over other species. Similarly, edible insects such as *Acheta domesticus* have been recognized as containing micronutrients such as iron, magnesium, manganese, phosphorus, potassium, selenium, sodium, and zinc [4]. It is worth highlighting that insects have been proposed as a source of minerals for human life, and it has been shown that the amount of iron, calcium, and zinc found in these insects is higher than in conventional food [31]. Likewise, a study conducted that *Acheta domesticus* has a high content of fatty acids of omega-3 and omega-6 quality, which makes it an energetic food [14].

Since the consumption of edible insects, called entomophagy, is still an unconventional practice in several cultures, it is essential to consider the functional properties of *acheta domesticus*, such as amino acid profile, solubility, and protein emulsion, as it influences its use as an ingredient in different types of meals. In this way, it can be introduced into people's diets since insect consumption is more accepted if they present a familiar appearance and odors.

Researchers propose *Acheta domesticus* as a species of interest in food industries thanks to its functional properties, such as water retention, which can contribute to the improvement of properties of bakery products [15]On the other hand, the high level of emulsification suggests that *Acheta domesticus* proteins may be beneficial for preparing ground meat and could contribute to food systems such as doughs, dressings, baby food, ice cream, and coffee whiteners. Finally, it highlights that insect-enriched foods have the potential to address iron deficiency, especially in countries most affected by malnutrition and food insecurity [30].

II. Material and Methods

To characterize and analyze the interrelation of factors and social actors for the *Acheta domesticus* flour production market, a non-experimental and transversal design was used, with an exploratory and descriptive scope. Likewise, the study used a qualitative approach to describe and interpret the opportunities related to the impact of the variables and social actors involved in the *Acheta domesticus* flour production market system. For this purpose, the methodological development followed a sequence of phases similar to those of other studies [32], [33], [34] which are detailed in the following Table 1.

TABLE I
PHASES OF THE METHODOLOGICAL DESIGN

Phase	Name	Partial scope
1	Determination of system variables and strategic social actors (stakeholders)	Definition and validation of variables and stakeholders within the system
2	Description of relationships between variables and stakeholders	Identification of the direct and indirect influence and incidence between variables and stakeholders
3	Identification of key variables and stakeholders	Hierarchization of the most critical variables and stakeholders
4	Analysis of the relationship between key variables and stakeholders for strategic market actions.	Diagnostics for market management and planning

In the first phase, after the contextual analysis of the flour production market in Peru, the variables that mainly influence this system were identified and diagnosed, as well as the social actors that participate both directly and indirectly. For this purpose, this phase was preceded by a documentary analysis and a PEST analysis, through which it is possible to explore the macro-environment of the flour production market and examine four main factors: political, economic, social, and technological. An Ishikawa diagram was also used to diagnose the root causes, identifying the main difficulties in the flour production market. This initial phase was supported by four experts and academics with knowledge in the sector to validate the identified variables.

In the second phase, the relationships between the variables and strategic participants described above were described following a structural analysis using the Direct Impact Matrix (DIM) and Indirect Impact Matrix (IIM). This impact relationship is measured in potential (P), strong (3), moderate (2), weak (1), or null (0), which is obtained by consensus, considering the statistical criteria. The system presents two ratings for each variable: dependence or direct (X) and motor or influence (Y), which are shown as coordinates (X; Y) on a Cartesian plane. It should be noted that the sum of the Y rows indicates the number of times the variable influences others. On the other hand, the sum of the columns X is the number of times an element depends on the others. With this unification of matrices, it is possible to show the relationship between motricity and dependence of the variables and groups of interest in the flour production market based on *Acheta domesticus*. Five experts were interviewed to validate these matrices.

Consequently, in the third phase, the variables and stakeholders were ranked using the MICMAC matrix (Matrix of Cross Impacts Multiplication Applied to a Classification), which is used to identify the critical strategic variables and participants through direct and indirect relationships. The results were placed on a Cartesian plane with dependency (X) and motor (Y) coordinates divided into four quadrants: power, critical, autonomous, and output. In addition, there is a fifth zone called platoon variables, located near the line or region next to the mean of the axes. Figure 2 presents the plane of motricity and dependence.

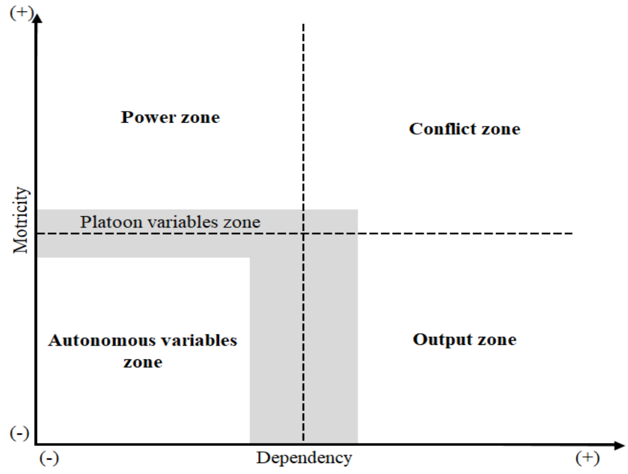

Fig. 2 Zones in the Cartesian plane for characterization.

In the fourth and last phase, a diagnosis was provided for directing and planning the production market, considering the impacts caused by the relationship between the variables analyzed in the previous phases and the participation of stakeholders in them. For this phase, a focus group of four experts was held to recognize the results obtained during the last phase.

III. RESULTS AND DISCUSSION

A. Results

According to the first phase established in the methodological design, the variables that intervene in the flour production market in Peru were determined, following the same categories of the PEST analysis, grouped into four sectors and presented in Table 2.

TABLE II
PRODUCTION MARKET VARIABLES

Code	Variable	Description
	Political/ Regulatory	
V1	State policies, rules, and regulations concerning consumption	Regulations focused on insect production and consumption
V2	Requirements for sanitary registration of the product (DIGESA)	
V3	Laws promoting healthy eating	Number of laws related to healthy eating
	Economic	
V4	Product costs	Flour production cost per 450 grams
V5	Profitability	IRR (Internal Rate of Return)
V6	Raw material cost	Collection cost of *Acheta domesticus*
V7	Cost of resources associated with the product	Variable costs for labor and care of the species
	Social	
V8	Food support programs	Number of government programs

Code	Variable	Description
V9	Consumer protection	Number of laws and regulations relevant to the production, distribution, and sale of foodstuffs
V10	Stigmatization associated with entomophagy.	% of the world population consuming edible insects
V11	Nutritional imbalance in children under five years of age	% malnutrition in children under five years of age
	Technological	
V12	Technological development	Flour processing steps based on *Acheta domesticus*
V13	Optimization of flour production	Bottleneck
V14	Supplier capacity and innovation	Service level
V15	Environmental impact	% carbon emission reduction

Similarly, it was possible to characterize the strategic social actors participating in the flour production market. On the one hand, insect producers, food production companies, private investment companies, and the entomological community were directly identified. On the other hand, indirectly, the Ministry of Agrarian Development and Irrigation (MINAGRI), Ministry of Production (PRODUCE), National Council of Science, Technology and Technological Innovation (CONCYTEC), Ministry of Health (MINSA) - General Directorate of Environmental Health (DIGESA) and Ministry of Development and Social Inclusion (MIDIS) were identified.

With the variables defined and validated by experts, the relationship between them was established using a Direct Impact Matrix (MID) to obtain a causal relationship, project them on a Cartesian plane with their assigned degree, and place them in the zone of motricity and dependence that warns us of a first reading of the critical variables of the system. However, to highlight the presence of hidden variables that could alter the stability of the system or, on the contrary, to confirm the scheme of relationships previously obtained, the Direct Impacts Matrix (DIM) was raised to a power n and an Indirect Impacts Matrix (IIM) was projected.

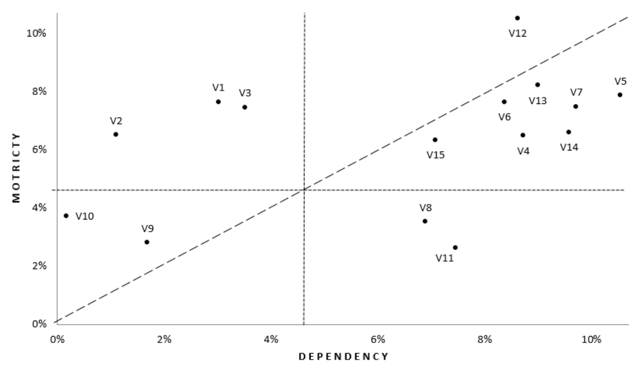

Fig. 3 Indirect Impact Matrix

Because the variables were validated and projected, the location of each variable within the different zones of the matrix was identified. The power zone is made up of influential variables but not very dependent; that is, because of their high mobility and low dependence on each other. The actions within the system have probably been oriented to the variables. In this zone, we have the following variables:

- V1: State policies, norms, and regulations on consumption
- V2: Requirements for sanitary registration of the product (DIGESA)
- V3: Laws providing for healthy eating

The conflict zone includes enormously influential and dependent variables; therefore, they are unstable by nature, and any action taken on them can alter the system's dynamics.

- V12: Technological development
- V5: Profitability
- V13: Flour production optimization
- V7: Cost of resources associated with the product
- V14: Supplier capacity and innovation
- V6: Raw material cost
- V4: Product cost
- V15: Environmental effect

In the output zone are the low-influence but highly dependent variables that are the result of the impacts obtained from the power and conflict variables; among them are:

- V8: Food support programs
- V11: Nutritional imbalance in children under five years of age

The zone of autonomous variables, comprised of variables with little influence and dependent variables, contains the following variables that have a minor impact on the system. They can be excluded without affecting the analysis developed.

- V9: Consumer protection

Finally, the platoon variables, which are in the intermediate zone of the Cartesian plane, do not present sufficient dependence and influence to be developed.

- V10: Stigmatization associated with entomophagy

As a next phase, the key variables belonging to the system were identified, which are found in the line of the plan and present greater mobility and, at the same time, are dependent. This enabled the identification and prioritization of the most influential and controlled variables established by the Direct Impacts Matrix to obtain a causal relationship. Subsequently, in the Indirect Impacts Matrix, adjustments were made to the hierarchy of certain variables, and the result is shown below:

- V12: Technological development
- V5: Profitability
- V13: Flour production optimization
- V7: Cost of resources associated with the product
- V14: Supplier capacity and innovation
- V6: Raw material cost
- V4: Product cost
- V15: Environmental effect

In the same way, this procedure was carried out to identify the influence and hierarchy of the system's stakeholders. This makes it possible to determine those stakeholders with greater mobility and dependence.

TABLE III
SOCIAL ACTORS ACCORDING TO AREAS OF POWER

High-powered players	
Highly influential and not very dependent on others.	A1: Insect producers A5: Ministry of Agrarian Development and Irrigation (MIDAGRI) A6: Ministry of Production (PRODUCE) A7: National Council for Science, Technology and Technological Innovation (CONCYTEC)
Actors of medium-power	
Highly influential and dependent on other actors.	A2: Food production companies A8: Ministry of Health (MINSA) - General Direction of Environmental Health (DIGESA)
Low power players	
Actors who have little influence but are highly dependent on others.	A4: Entomological community A3: Private investment companies A9: Ministry of Development and Social Inclusion (MIDIS)

B. Discussion

According to expert consensus, the evidence presents an unstable system. The system's instability implies a dispersion of the variables along the bisector, especially when they are in the upper right quadrant (conflict zone). However, the results show that the most sensitive variables are V12 and V5, technological development, and profitability.

Based on the results obtained, technological development (V12) is the most relevant variable in the system because it presents the most incredible mobility and dependence, which coincides with what has been suggested by various authors. Few of them point out that technology, both for the cultivation and processing of edible insects, is a specific barrier for scaling up to commercial and scale production of insect-based powder [35]. Currently, there is a lack of knowledge about emerging technologies for edible insect processing that results in the application of inefficient conventional processes and can impact product quality [36].

To achieve improved flour production, recent developments in the agri-food sector have shown that emerging technologies are promising alternatives for sustainable green processing [37], capable of improving the safety and quality of final products and improving processing efficiency [38]. Nonetheless, the knowledge about edible insect production is scant, and producers have limited experience [39] which can hinder the diffusion of these emerging technologies.

On the other hand, profitability in the food market (V5) was also presented as a critical variable related to the flour production market from *Acheta domesticus*. This is due to the acceptance of insects in Western countries and the increasing demand mainly for profitability reasons [40]. One of the main reasons is the low cost of feeding insects because they can be obtained from various wastes [6]. However, there is a cost gap in specific production techniques, such as freeze-drying, which allows for maintaining high quality with nutritional value and long shelf life [7]. For this reason, it is sought to replace with comparable techniques with lower energy-related costs.

With the limitations presented on the cost gap, insect breeding is still destined for specific markets since plant installation, equipment costs, and production at the industrial level are expensive [41]. This is because technification research is still required for the production of flour and conversion of ingredients at similar cost levels to protein concentrates in the market [6]. Therefore, it is necessary to achieve cost reduction to obtain income opportunities at the industrial level in flour production [41].

Concerning the social actors of the system, insect producers were identified as one of the high-powered groups. They made up the primary insect sector, thus representing the beginning of the production system. Innovations in insect production can increase competitiveness and offer new market opportunities [35]; however, knowledge about technologies for edible insect production is scarce, and producers have limited experience [42]. On the other hand, legal regulations and social factors can also be a constraint in production [43]. As mentioned in this research, one of the virtues of edible insect production is the low ecological footprint it generates, unlike traditional livestock systems [44]. In this context, insect farming emerges as an environmentally friendly alternative, and to minimize its environmental impact, insect producers must have sustainable systems and facilities [45].

The evidence found in the research aims to achieve a better understanding of the flour production market based on *Acheta domesticus* in Peru. Although we tried to reach a consensus among the experts on the proposed system accompanied by reflection, it is convenient to consider structural analysis's limits, so it should not be taken as a definitive and indisputable means. This research can be used as a resource for future studies that seek to achieve a change in the industry and find a starting point. This is a scope for factors that present a greater responsibility within the system because, as noted, this industry is constantly changing and is sensitive to various factors that can be transformed over time.

IV. CONCLUSION

The evidence obtained through the structural analysis made it possible to characterize the flour production market based on *Acheta domesticus*, considering the variables that play a role in its growth and development in Peru. There were fifteen variables, of which six were considered vital, with technological development and profitability being the most sensitive within the system. All the critical variables found are part of the technological and economic aspects. Emerging technologies have a significant impact on the development of the flour production market and can guide it towards a massive scope. They could also result in cost reduction by optimizing the production process.

Nine social actors, both direct and indirect, that influence the sector were also validated. Thanks to the hierarchical ranking, insect producers were identified as the most relevant and robust since they are directly involved in producing inputs based on edible insects and represent the beginning of the production chain. The entomological community and the Ministry of Development and Social Inclusion were identified as less relevant actors, which, although they are related to some of the variables mentioned in the study, were classified as secondary issues that, in the end, do not have a significant impact on the system in question.

Finally, the methodology used was convenient for elaborating the structural characterization of the variables and social actors of the flour market from *Acheta domesticus* in Peru. Based on the findings and conclusions presented, this will allow a starting point for the strategic planning of future scenarios in the medium or long term.

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