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ABSTRACT

The sustainability of poultry and swine production within the integration system faces a dilemma between economic success and the negative impacts generated on the environment and society. This study aims to analyse the profile of rural producers operating within the integration system and discuss aspects associated with the economic, social, and environmental dimensions of the activity. Using a pre-existing dataset generated from a questionnaire that mapped the characteristics of integrated producers from 37 municipalities in the western mesoregion of Santa Catarina, Brazil, a quantitative cluster analysis method was employed to address the proposed objective. The findings reveal four distinct groups of producers, each exhibiting specific characteristics related to age, education, profitability of the lots, and satisfaction, among other factors. It was not possible to consider the analysed clusters as fully sustainable, as there were distinctions between the three pillars of sustainability, indicating a lack of balance among them. This, coupled with the diversity of the groups, highlights the influence of various factors on the producers' attitudes towards their activities and allows for the identification of critical aspects, opportunities, and motivators. The study provides insights for integrating companies, which may use this profile analysis to tailor their support strategies to address the specific challenges faced by each group. Additionally, the research supports the development of targeted public policies aimed at promoting sustainability in this sector.

Keywords: Agribusiness. Integration System. Sustainable Production. Rural Producer.

RESUMO

A sustentabilidade da produção de aves e suínos no sistema de integração enfrenta o dilema entre o sucesso econômico e os impactos negativos gerados para o meio ambiente e para a sociedade. Este estudo tem por objetivo analisar o perfil de produtores rurais que atuam no sistema de integração e discutir aspectos associados à dimensão econômica, social e ambiental da atividade. A partir de uma base de dados pré-existente, gerada por um questionário que mapeou características de produtores integrados de 37 municípios da mesorregião Oeste de Santa Catarina, Brasil, fez-se uso do método quantitativo de análise de cluster para responder ao objetivo proposto. Os achados revelam quatro grupos distintos de produtores, que apresentam características específicas em relação à idade, escolaridade, rentabilidade dos lotes e satisfação, por exemplo. Não foi possível considerar os clusters analisados plenamente sustentáveis - houve distinção entre os três pilares da sustentabilidade e, portanto, não se constatou um equilíbrio entre eles. Esse fato, somado à diversidade dos grupos, indica a influência de diferentes fatores na atitude dos produtores em relação à atividade e permite a identificação de aspectos críticos, oportunidades e motivadores. O estudo fornece *insights* para as empresas integradoras, que podem utilizar essa análise de perfil para adaptar suas estratégias de suporte aos produtores considerando os desafios específicos de cada grupo. A pesquisa também fornece suporte para o desenvolvimento de políticas públicas assertivas, voltadas para a sustentabilidade deste segmento.

Palavras chave: Agronegócio. Sistema de Integração. Produção Sustentável. Produtor Rural.

INTRODUCTION

The production of poultry and swine for human consumption plays a vital role in the Brazilian agribusiness, which accounts for a substantial portion of the global output. In 2022, Brazil ranked as the second-largest global producer of chicken meat (14.5 million tonnes) and the fourth-largest producer of pork (4.9 million tonnes) (Brazilian Animal Protein Association, 2023). During the same year, the Southern Region of the country encompassed 59.9% of chicken slaughters and 28.5% of pig slaughters (Epagri-Cepa 2023).

Santa Catarina state, out as a hub for these productive activities, leading in slaughters and exports of animal products within the national territory (Brazilian Animal Protein Association, 2023). The poultry and swine production in the state of Santa Catarina is characterized by the integration system, a production configuration that enables the agro-industry to meet its demand in both quantity and quality, while ensuring the producer the commercialization of their entire production (Bueno; Dario, 2022).

Due to population growth, agribusiness faces the challenge of ensuring food security for the population and producing food sustainably (Kakani *et al*., 2020). In this context, production growth does not occur in isolation from global concerns about sustainability, and sustainable development increasingly has effects on food supply chains (Parrot *et al*. 2022). The holistic approach to sustainability, known as Elkington's Triple Bottom Line (1994), emphasizes the need for balance among economic, social, and

environmental aspects to achieve sustainability (Geissdoerfer *et al*., 2017).

Ensuring sufficient food production while providing economic returns and well-being for rural producers is a condition for the sustainability of agribusiness (Ching, 2008). In the Brazilian production of poultry and swine, positive and significant economic results are observed, along with recognition of the environmental impact of these activities, particularly concerning the produced waste with high pollution potential. Furthermore, the integration system can impact social dynamics between producers and the agro-industry (Tavares, 2023), raising questions about the sustainability of this relationship. Furthermore, there is a quest to deepen the discussion on the form of producers' participation in the current capitalist agricultural system, as well as the role that the State should play (Zanella; Milhorance, 2016).

Despite the increasing discussions on sustainability in agribusiness over the last decade, there is a need for more exploration. Productions conducted between 2017 and 2021 reveal research opportunities, focusing on four main areas: development indicators, eco-innovation, corporate social responsibility, and socio-environmental aspects (Arruda *et al*., 2022).

Massuca *et al*. (2022) point out that many studies on sustainability in agribusiness do not discuss the social dimension. To address this gap, this study aims to simultaneously discuss economic, environmental, and social aspects in the context of agribusiness, with a focus on pig and poultry producers in the Western region of Santa Catarina, Brazil. It aims to answer the following research question: What is the profile of rural producers operating in the integration system and its association with environmental, economic, and social aspects? Thus, the present study aims to analyze the profile of rural producers involved in the integration system, discussing aspects associated with the economic, social, and environmental dimensions of the activity.

This study contributes to expanding the discussion of the economic, social, and environmental sustainability of a significant agribusiness activity in an emerging country. The insights obtained from the research can inform the formulation of public policies that encourage the continuity of producers in the field and contribute to a more sustainable production of poultry and swine, which is considered valuable given that the absence of efficient government policies poses a barrier to the sustainability of agribusiness (Brenya *et al*., 2023). The findings also have the potential to contribute to the advancement of the 2030 Agenda, particularly in terms of Sustainable Development Goal (SDG) 12 - Responsible Consumption and Production.

SUSTAINABILITY, AGRIBUSINESS, AND INTEGRATION SYSTEM

Sustainability, a common yet multifaceted term, lacks a unified definition in the literature (Moore *et al*., 2017). For this study, the concept of sustainability is adopted as the "Triple Bottom Line," coined by Elkington (1994), promoting balance among economic, environmental, and social aspects. Over the years, authors such as Torresi *et al.* (2010) and Geissdoerfer *et al*. (2017) have followed the same theoretical framework as Elkington (1994), asserting that sustainability is a balanced and interconnected relationship between the economy, social performance, and the environment. Achieving socioeconomic sustainability is not possible without environmental sustainability, for example.

Global concerns about sustainability permeate various sectors, including agribusiness (Brenya *et al*., 2023). Characterized by economic activities related to agriculture, livestock, and other productive segments, agribusiness encompasses a range of production chains from inputs, through the primary production of raw materials, processing, and distribution, involving different actors in the logistics chain until reaching final consumers (Barros, 2022).

In the Brazilian context, agribusiness exerts a remarkable economic influence, transforming the country from an importer to a major exporter of agricultural commodities (Estadão Summit Agro, 2022). Animal protein, especially poultry and pork, is one of the traded commodities that distinguishes Brazil in the international market - in 2022 alone, 4,822 thousand tonnes of chicken meat and 1,120 thousand tonnes of pork were exported (Brazilian Animal Protein Association, 2023).

Given the significant representation of Brazilian agribusiness production, it is evident that the expansion and modernization of the sector have brought both positive and negative economic, social, and environmental impacts. There is an interest among involved stakeholders to seek a balance between socioeconomic development and the preservation of natural resources, contributing to the sustainable development of the country (Rosano-Peña *et al*., 2015).

Given its broad scope, encompassing various activities directly and indirectly, certain segments of agribusiness exhibit specific characteristics. For instance, the agro-industrial chain of pork and poultry lacks attention when it comes to sustainability. Especially in Santa Catarina, the largest producer and exporter in Brazil (Brazilian Animal Protein Association, 2023), production

is marked by the integration system. In this system, the relationship between agro-industry and integrated producers is established through integration contracts, aiming to transact a specific agricultural product for payment (Confortini; Zimatore, 1982).

Contracts provide legal security in the commercial relationships between the parties and contribute to the competitiveness of the agro-industrial sector (Silva *et al*., 2022). Despite the theoretical interdependence and balance in the integration system, due to the agro-industry holding market power, its demands and decisions tend to prevail over other involved parties (Stoffel; Rambo, 2022). This explains why the rural producer is considered the weak link in the production chain (Zylberzstajn; Neves, 2000).

Previous studies that analyzed the scenario of integrated producers in the Brazil Southern region identified asymmetries in the integration relationship. For example, Jesus (2010) indicates that the relations between the parties cannot be considered a partnership precisely due to the imposition of determinations by the companies, requiring producers to endure exhaustive working hours, health risks, and social interaction losses. Sopeña *et al.* (2018) identified dissatisfaction with remuneration, considered low by producers, and a lack of negotiation power, supporting the decharacterization of the partnership format of work.

On the other hand, Zanin *et al.* (2020) argue that the presence of the integration system is beneficial for properties to achieve higher levels of sustainability. According to the authors, agro-industry plays a role in promoting and encouraging changes and innovations, and should also promote social conditions that benefit rural producers and encourage them to stay in the activity. The findings of the mentioned studies indicate the importance of thoroughly analyzing social aspects of agribusiness, which are often overlooked in research (Massuca *et al*., 2022).

In general, studies focusing on sustainability in agribusiness tend to concentrate their efforts on observing and proposing indicators of development, eco-innovation, corporate social responsibility, and socio-environmental aspects (Arruda *et al*., 2022). There is evidence that agribusiness can act as a facilitator for sustainable development in developing countries (Munonye; Esiobu, 2017), indicating the relevance of analyzing sustainability in its economic, social, and environmental aspects in the context of poultry and pig production within the integration system.

METHODOLOGY

The present study adopts a quantitative approach and employs cluster analysis, also known as clustering analysis, as the central method. Cluster analysis aims to group objects based on their characteristics (Hair *et al*., 2009). This technique was used to assess the clustering of variables related to the profile and economic, social, and environmental aspects of pig and poultry production in the west of Santa Catarina. This allows an evaluation of the sustainability of these activities from the perspective of integrated producers.

The data used in this analysis derive from a study conducted by Maldaner (2023), involving 401 poultry and pig producers from 37 municipalities in the Western mesoregion of Santa Catarina, Brazil, operating in the integration system. The applied questionnaire consisted of 95 questions that, among other aspects, aimed to describe the profile of integrated producers, property and integration system characteristics, production management, succession process, satisfaction, and impacts on personal life. Data collection, as described in Maldaner (2023), took place between October 2021 and November 2022, with on-site application in the properties and online questionnaire submission for the producers.

Considering the defined study objective and the researcher's need to assess the relevance of variables for inclusion in the cluster analysis (Hair *et al*., 2009), 17 variables were selected. These variables were chosen to represent the profile of producers and enable the analysis of economic, social, and environmental aspects of productive activities. Following the definition of variables, a preliminary analysis of the database was conducted to assess data consistency. Upon identifying missing responses in one or more variables, 186 observations were excluded. Thus, the analysis presented in the next section was conducted based on the data from 215 observations.

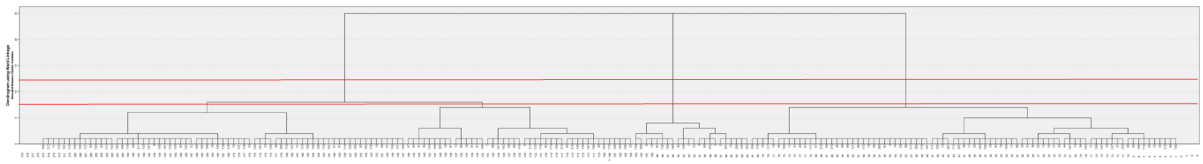
The responses from the 215 integrated producers were coded to enable the quantitative analysis of the data. The data preparation for subsequent importation into the Statistical Package for the Social Sciences (SPSS 20) software was carried out in a Microsoft Excel spreadsheet.

In applying the cluster analysis, certain choices need to be made. It is possible to work with hierarchical and non-hierarchical clustering, each with its own advantages and disadvantages. Considering the research objective, the decision was made to use the hierarchical method, which provides a graphical representation in the form of a tree, known as a dendrogram. The dendrogram illustrates how clusters are combined until a single cluster is formed (Hair *et al*., 2009), facilitating analysis and understanding.

For the composition of clusters, the Ward method was chosen as the clustering algorithm, being one of the most popular methods (Corar *et al.,* 2014) widely used in the literature. "This method tends to result in clusters of approximately equal sizes due to its minimization of internal variation" (Hair *et al.*, 2009, p. 429). The squared Euclidean distance was used as the measure of similarity, recommended by Hair *et al.* (2009) when adopting the Ward method.

Fávero *et al.* (2009) emphasize that when using the hierarchical method, it is the researcher's responsibility to analyze the most appropriate number of clusters, as there is no objective procedure to determine it. Thus, to define the number of clusters, an exploratory analysis was conducted using the hierarchical method. Through the dendrogram (Figure 1), it was possible to identify the proposed clusters for the data. Considering the research objective, it was found that an analysis based on three or four clusters would be most suitable. For the final definition of the number of clusters, the SPSS was requested to cluster the data into three and four clusters, considering the Ward method and squared Euclidean distance.

Figure 1 | Dendrogram resulting from the hierarchical test of the data



Source: Elaborate by the authors (2023).

Subsequently, the Kruskal-Wallis test was applied to assess the significance of the study variables in the three and four-cluster groupings. For the grouping of observations into three clusters, the presence of three non-significant variables (sig > 0.05) was identified, while in the four-cluster grouping, all variables showed significance (sig < 0.05), except for variables 3 and 17 ("Generation" and "Existence of Water Scarcity," respectively), as presented in Table 1. Despite this, it was chosen to retain them in the analysis, as they did not significantly impact the proposed discussion, given that the other variables related to the profile and environmental aspects proved significant for the groupings. Therefore, the grouping into four clusters, considered by the researchers as the most suitable to address the research objective, was adopted.

Table 1 | Kruskal-Wallis test for four-cluster grouping

ID	Chi-Square	df	Asymp. Sig	ID	Chi-Square	df	Asymp. Sig
1	113,370	3	,000	10	28,064	3	,000
2	87,299	3	,000	11	26,935	3	,000
3	5,015	3	,171	12	30,437	3	,000
4	18,158	3	,000	13	27,846	3	,000
5	19,109	3	,000	14	41,045	3	,000
6	10,960	3	,012	15	111,221	3	,000
7	26,456	3	,000	16	8,861	3	,031
8	22,927	3	,000	17	1,340	3	,720
9	79,484	3	,000				

Source: Elaborate by the authors (2023).

The results obtained with the assistance of SPSS were exported to a Microsoft Excel spreadsheet, where descriptive statistics were applied for the quantification of variables and subsequent description of each cluster. Following that, based on the literature, a discussion was conducted on the profile and sustainability aspects of the productive activity, presented in the following section.

PRESENTATION OF RESULTS

The data obtained from the SPSS analysis were exported to a Microsoft Excel spreadsheet, where descriptive statistics were applied for quantifying the variables and subsequently describing each cluster. Following this, based on the literature, the discussion of the profile and sustainability aspects of the productive activity was conducted, as presented in the following section.

Table 2 | Cluster composition

Cluster	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Number of grouped observations	22	81	43	69
Representativity in relation to the sample	10,2%	37,7%	20,0%	32,1%

Source: Elaborate by the authors (2023).

Through the use of descriptive statistics, Table 3 was constructed, presenting the responses of the 215 producers grouped into their respective clusters for each study variable.

Table 3 | Description of cluster characteristics

Variable	Description	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Education	Incomplete primary education	4,5%	48,1%	4,7%	-
	Completed primary education	22,7%	25,9%	4,7%	1,4%
	Incomplete secondary education	9,1%	9,9%	16,3%	5,8%
	Completed secondary education	40,9%	14,8%	34,9%	36,2%
	Incomplete higher education	4,5%	1,2%	4,7%	13,0%
	Completed higher education	18,2%	-	32,6%	30,4%
	Completed technical education	-	-	2,3%	5,8%
	Postgraduate	-	-	-	4,3%
	Master's degree	-	-	-	1,4%
	Doctorate	-	-	-	1,4%
Age	Up to 18 years	-	-	-	4,3%
	Between 18 and 25 years	-	-	7,0%	13,0%
	Between 26 and 35 years	22,7%	3,7%	39,5%	40,6%
	Between 36 and 45 years	45,5%	18,5%	27,9%	29,0%
	Between 46 and 55 years	22,7%	40,7%	20,9%	11,6%
	Between 56 and 65 years	9,1%	27,2%	4,7%	1,4%
	Over 66 years	-	9,9%	-	-
Generation	First generation	63,6%	59,3%	44,2%	53,6%
	Second generation	31,8%	37,0%	39,5%	36,2%
	Third generation	4,5%	3,7%	14,0%	8,7%
	Fourth generation	-	-	2,3%	1,4%
Integration time	Up to 5 years	22,7%	14,8%	16,3%	36,2%
	Between 6 and 10 years	-	14,8%	16,3%	18,8%
	Between 11 and 20 years	45,5%	40,7%	41,9%	36,2%
	Between 21 and 30 years	22,7%	22,2%	11,6%	7,2%
	Between 31 and 40 years	4,5%	6,2%	11,6%	-
	Between 41 and 50 years	4,5%	-	2,3%	1,4%
	Between 51 and 60 years	-	1,2%	-	-
	Over 60 years	-	-	-	-
Lot Productivity Parameters	Exceed the company's desired parameters	36,4%	4,9%	18,6%	15,9%
	Meet the company's desired parameters	63,6%	84,0%	79,1%	79,7%
	Do not meet the company's desired parameters	-	11,1%	2,3%	4,3%
Lot Profitability Parameters	Exceed the company's desired parameters	27,3%	4,9%	14,0%	11,6%
	Meet the company's desired parameters	63,6%	79,0%	76,7%	85,5%
	Do not meet the company's desired parameters	9,1%	16,0%	9,3%	2,9%
Evaluation of Activity Profitability by the Producer	Very profitable (very profitable)	9,1%	4,9%	11,6%	14,5%
	Profitable (gives a little profit)	40,9%	64,2%	58,1%	84,1%
	It is not very profitable (breaks even)	45,5%	27,2%	27,9%	1,4%
	It is not profitable (it gives a loss)	4,5%	3,7%	2,3%	-

Debt Existence	Yes	90,9%	65,4%	86,0%	94,2%
	No	9,1%	34,6%	14,0%	5,8%
Daily Working Hours	Up to 4 horas	-	18,5%	-	24,6%
	4-8 hours	4,5%	38,3%	7,0%	46,4%
	8-12 hours	18,2%	17,3%	23,3%	15,9%
	12-16 hours	50,0%	23,5%	25,6%	13,0%
	16-20 hours	13,6%	2,5%	30,2%	-
	20-24 hours	13,6%	-	14,0%	-
Successor Existence in the Property	Yes	50,0%	44,4%	55,8%	85,5%
	No	50,0%	55,6%	44,2%	14,5%
Activity Impact on Health	Yes	68,2%	39,5%	41,9%	13,0%
	No	31,8%	60,5%	58,1%	87,0%
Possibility of Quitting the Activity	Absolutely yes	13,6%	4,9%	4,7%	1,4%
	Maybe yes	22,7%	18,5%	4,7%	2,9%
	Depends	18,2%	32,1%	34,9%	13,0%
	Maybe no	4,5%	16,0%	9,3%	11,6%
	Absolutely no	40,9%	28,4%	46,5%	71,0%
Satisfaction with the Activity	Totally Satisfied	9,1%	3,7%	11,6%	18,8%
	Satisfied	40,9%	56,8%	53,5%	72,5%
	Indifferent	18,2%	9,9%	16,3%	7,2%
	Dissatisfied	31,8%	22,2%	16,3%	1,4%
	Totally Dissatisfied	-	7,4%	2,3%	-
Feeling Towards the Integrator Company	Business Partner	27,3%	46,9%	44,2%	87,0%
	Not Valued	40,9%	34,6%	30,2%	11,6%
	Exploited	4,5%	3,7%	9,3%	1,4%
	Slave to the System	27,3%	14,8%	16,3%	-
Animal Concentration (Animals per Hectare)	Up to 500	-	86,4%	62,8%	92,8%
	501-1000	-	4,9%	14,0%	2,9%
	1001-2000	-	4,9%	18,6%	4,3%
	2001-3000	18,2%	3,7%	4,7%	-
	3001 e 4000	22,7%	-	-	-
	4001 e 5000	18,2%	-	-	-
	5001 e 6000	4,5%	-	-	-
	6001 e 7000	4,5%	-	-	-
	Over 7001	31,8%	-	-	-
Waste Absorption Capacity	Yes	40,9%	54,3%	67,4%	40,6%
	No	59,1%	45,7%	32,6%	59,4%
Water Scarcity Existence	Yes	27,3%	38,3%	37,2%	31,9%
	No	72,7%	61,7%	62,8%	68,1%

Source: Elaborate by the authors (2023).

In summary, based on Table 4, it is observed that Cluster 1 comprises poultry and swine producers with average education, middle-aged and elderly, from the first generation of family producers, with over a decade of integration experience. Economically, they meet the company's desired parameters in both productivity and profitability of batches, but still have debts and consider the activity less profitable. In this group, the working hours are high (at least 12 hours per day), which may result from the high concentration of animals on properties in this Cluster.

Despite the positive economic results indicated, Cluster 1 is predominantly composed of producers contemplating quitting the activity, likely motivated by a sense of undervaluation, feeling like slaves to the system, and overall dissatisfaction with the activity. In environmental terms, the significant concentration of animals mentioned earlier may be the determining factor for most properties in this Cluster lacking the capacity to absorb animal waste.

Cluster 2, on the other hand, consists of producers with lower education, older age (at least 46 years old), members of the first generation of integrated family producers who have been in the integration system for at least a decade. There are even producers with over 50 years in the activity in this group. Despite a significant portion of Cluster 2 producers indicating compliance with productivity and batch profitability parameters, this group has the highest proportions of producers who do not meet the desired parameters. Although 65.4% of Cluster 2 producers have debts, this is the Cluster with the lowest percentage of indebtedness among the others, suggesting a low intention for investments or improvements in property infrastructure, for example. Nevertheless, the majority of grouped producers consider the activity profitable.

The daily workload dedicated by producers in Cluster 2 are relatively lower compared to other clusters, predominantly ranging from 4 to 8 hours for activities. In this group, the majority of properties lack a successor and do not perceive that the work routine has interfered with health. There are significant indices of producers contemplating quitting the activity, and the highest proportion of producers claiming to be totally dissatisfied with the activity is observed (7.4% of Cluster 2). Despite these indications, 46.9% of producers in this group consider themselves business partners, which may reflect the profile of older producers whose trusting relationship with the integrator is established. However, it should be highlighted that, when combined, the majority of

producers feel undervalued, enslaved by the system, or exploited.

Regarding environmental aspects, Cluster 2 shows a predominance of a low concentration of animals per hectare, which may be reflected in the fact that most properties can absorb all the waste produced and do not suffer from water shortages.

Analyzing the characteristics of Cluster 3, we identify the presence of producers with high education – 34.9% of them have completed higher or technical education. Mostly, these are young producers aged between 26 and 35 years (39.5%), from the first and second generation of producers, working in integration for at least 11 years. Cluster 3 contains the largest proportion of producers whose productivity and batch profitability parameters surpass those desired by the company when compared to other clusters. The majority of producers in this cluster consider the activity profitable (58.1%) and indicate the existence of debts.

Regarding working hours, Cluster 3 has the highest percentages of producers dedicating 16 to 24 hours daily to the production of swine and poultry. The majority of producers in this group have successors and believe that routine activities do not affect health. Furthermore, satisfied or totally satisfied producers prevail (65.1%), reflecting also in 44.2% of producers who consider themselves business partners and the majority of producers who do not contemplate abandoning swine and poultry production. Regarding environmental aspects, Cluster 3 is primarily composed of properties with a low concentration of animals, possessing the capacity to absorb produced waste, and not experiencing water shortages for production.

In Cluster 4, producers with the highest educational attainment among the analyzed groups are concentrated, including those holding postgraduate, master's, and doctoral degrees. Mostly, they are young producers, aged up to 35 years. 53.6% of this group represents the first generation of the family engaged in integration, allowing us to infer that young producers have been investing in swine and poultry activities. This is reinforced by the fact that 36.2% of Cluster 4 producers have been in the integration system for 5 years or less.

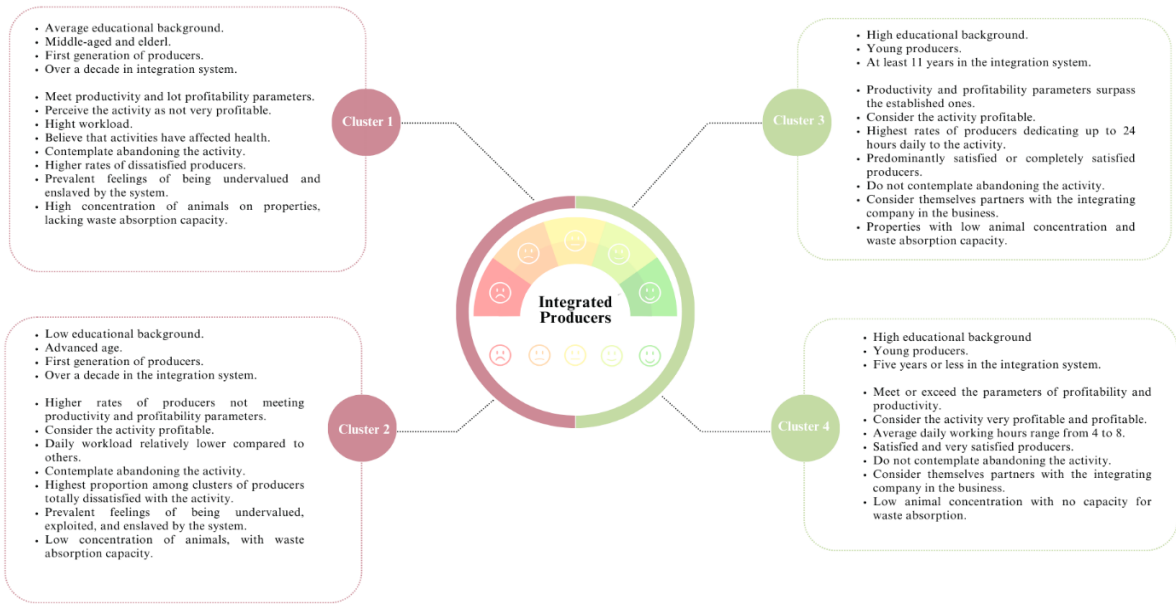
Cluster 4 has the highest percentage of producers with debts (94.2%), while also being the group that considers the activity very profitable (14.5%) and profitable (84.1%) the most among the analyzed groups. Other economic parameters are also positive, with the vast majority of producers

meeting or surpassing established profitability and productivity parameters.

The daily working hours of Cluster 4 producers mainly range from 4 to 12 hours. In 85.5% of cases in this group, the existence of a successor on the property is confirmed, and 87.0% of producers do not perceive interference of activities in health. Cluster 4 also has the highest proportion of satisfied producers (72.5%) and very satisfied (18.8%) with integration activities, reflected in the index of 71.0% of producers categorically indicating no possibility of quitting the activity and 87.0% considering themselves business partners with the integrating company.

Finally, the environmental aspects observed in Cluster 4 reveal the predominance of properties with a low concentration of animals but facing challenges in absorbing all waste produced during poultry and swine production. Water scarcity, like in other clusters, is not reported as a problem by 68.1%.

Figure 2 | Prominent characteristics of the analyzed clusters



Source: Elaborate by the authors (2023).

Figure 2 seeks to summarize the results, considering the most striking characteristics of each cluster. Based on the insights gained from the cluster analysis, the next section presents a discussion of the results from the perspective of sustainability, considering economic, social, and environmental aspects.

DISCUSSION OF RESULTS

The presented results reveal the predominance of certain characteristics in the analyzed clusters, highlighting differentiation among the groups and providing discussion points. In Cluster 1, producers of various ages are concentrated, exhibiting features of discontent and dissatisfaction. Despite meeting economic parameters, they face profitability challenges and work long hours. In Cluster 2, older producers are observed, with a mix of satisfaction and concerns about the future. They have a lower workload and uncertainties regarding succession. In Cluster 3, young and educated producers are found, showing high satisfaction and achieving positive economic and environmental outcomes. They hold a positive view of the activity and are more inclined to continue in it. Finally, in Cluster 4, young producers with high educational levels are concentrated, displaying good economic results but facing environmental management challenges. They express high satisfaction and perceive the activity as highly profitable.

The level of education seems to be a characteristic influencing producers' satisfaction perception and the economic outcomes of the activity. In Cluster 4, where producers have high education levels, the highest levels of satisfaction with the activity among the analyzed groups are found, along with the best lot profitability indices. Conversely, in Clusters 1 and 2, where producers with low education levels predominate, high levels of dissatisfaction and a predisposition to abandon the activity are observed.

When examining the producers' profile concerning age, it is possible to draw some interesting inferences. Among older producers, a more prominent inclination to abandon the activity is identified (Clusters 1 and 2). This may be influenced by uncertainties regarding family succession in the property and the impact of activities on health, as evidenced by Cluster 1.

Among younger producers, the majority, as revealed by data from Clusters 3 and 4, do not consider abandoning the activity. These are the individuals obtaining the best results in terms of lot productivity and profitability. In the two clusters of younger producers, the existence of successors is also identified, reflecting these producers' positive sentiment towards the integrator – the majority considers themselves business partners. The positive sentiment towards the integration system could be a motivating factor for the future generation to stay in the activity.

Regarding indebtedness, Cluster 4 exhibits the highest percentage of producers indicating the existence of debts (94.2%). These producers are young, highly educated, and demonstrate good productivity, profitability, and satisfaction indices. Considering that producers in this group have lower daily production hours, debts may represent investments in technologies to optimize production methods.

It is important to highlight that debts are significantly present in all analyzed clusters, and many of them may be associated with modernizing pig and poultry farming. In the integration system, products must comply with production standards and modernization requirements established by agro-industries, often making them dependent on bank financing (Souza *et al*., 2023). Although high investments are economically viable, they may result in a long return period, as demonstrated in the study by Stoffel and Rambo (2022), requiring sacrifices in the family and on the property, especially for small producers (Souza *et al*., 2023).

Working hours are another relevant aspect to be analyzed, revealing asymmetries. While the high working hours observed in Cluster 1 are reflected in reported health damages, Cluster 3 shows a significant percentage of producers claiming not to have suffered health impacts, even while dedicating up to 24 hours to the activity. This perception prompts reflections on individual satisfaction and the relationship with one's work - dissatisfaction is higher in Cluster 1 compared to Cluster 3.

It is possible to infer a correlation between satisfaction with the activity and lot profitability: in Clusters 3 and 4, where the majority of producers are entirely satisfied and satisfied with productive activities, the best profitability indices are observed. Consequently, this situation reflects on the producers' perception of the profitability of the activity, which, in both mentioned clusters, is viewed as profitable or highly profitable.

Finally, in environmental terms, a general analysis reveals that, interestingly, the concentration of animals on properties does not seem to be a determining factor for waste absorption conditions and water scarcity. In Cluster 4, for example, even with the predominance of properties with low animal concentration, the absence of the capacity to absorb all waste can be identified. This finding alerts to the pollutant potential of the activity and the need for joint discussion of alternative solutions for treating waste from productive activities. When used correctly, pig waste, for instance,

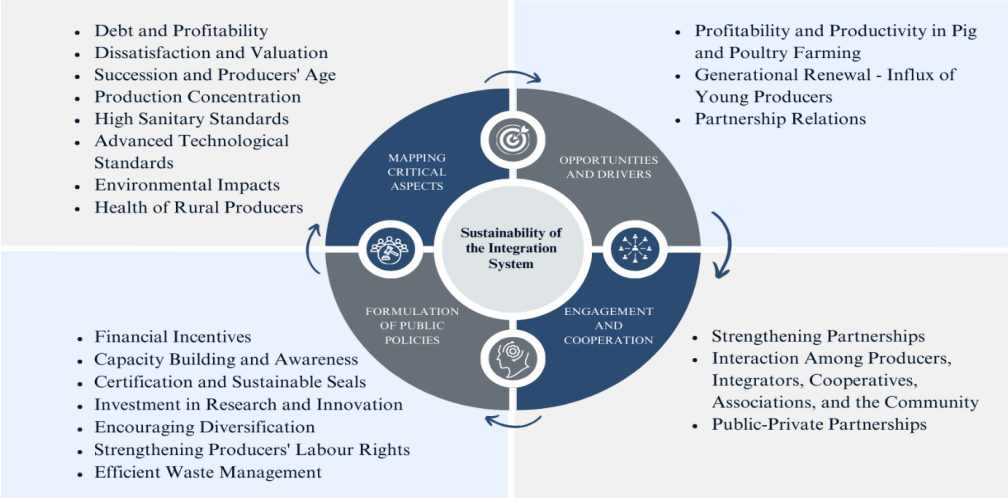
can generate positive outcomes for both grain cultivation and soil quality (Antonelli *et al.,* 2019).

The sustainability of pig farming in western Santa Catarina has been addressed by de Camargo *et al.* (2018), Zanin *et al.* (2020), and Kruger *et al.* (2022). Despite adopting different approaches, all three studies observe asymmetries among environmental, social, and economic dimensions. The social dimension was classified as unsustainable in all properties by de Camargo *et al.* (2018), and the environmental dimension presented the greatest negative impacts in Kruger et al.'s analysis (2022), for instance. This perception of distinction among the three pillars of sustainability is corroborated by this study: it is not possible to consider the analyzed clusters fully sustainable.

For instance, Cluster 4 presents satisfactory indices in the economic realm, but there is an imbalance in environmental terms due to the absence of waste absorption capacity. In Cluster 3, the good performance in environmental aspects is evident, but producers have high workloads and report feelings of exploitation and lack of appreciation, affecting the quality of life for those integrated. In this study, akin to de Camargo *et al.* (2018), the social context of integrated producers is highlighted: even in clusters where satisfied producers predominate, there still exists a sense of undervaluation and exploitation in relation to the integrator.

In summary, the analysis reveals a variety of challenges and opportunities for rural producers involved in the integration system. Dissatisfaction, financial challenges, lack of successors, environmental impacts, and health issues are some of the critical factors that can threaten the sustainability of the activity. The entry of young producers into productive activities, with technical knowledge and high education levels, coupled with the strengthening of partnership relations, is viewed as opportunities, primarily driven by the perceived profitability of productive activities. Corporate strategies for engagement and collaboration are considered crucial for sustainability in a vertical integration chain (Pohlmann *et al*., 2020), involving all stakeholders in the supply chain (Zanin *et al*., 2020).

Figure 3 | Sustainability of the integration system: findings and reflections



Source: Elaborate by the authors (2023).

From the identification of critical factors, mapping of opportunities and motivators, and acting in an engaged and cooperative manner, it is possible to discuss the development of public policies for the sector, playing a fundamental role in supporting and promoting sustainability, and supporting economic activities, including poultry and pig production in the integration system. The specific approach of public policies will depend on regional characteristics, specific challenges faced by producers, and governmental priorities. An integrated approach involving multiple stakeholders and considering economic, social, and environmental aspects is essential to ensure the long-term sustainability of poultry and pig production in the integration system. To synthesize the findings and reflections of the research, the presented framework in Figure 3 was constructed.

The sustainability of poultry and pig production in the integration system, akin to agribusiness, faces the dilemma between economic success and the negative impacts generated on the environment and society. This dilemma lacks a singular solution, as the research findings reveal distinct expectations and perceptions among individuals. Nevertheless, adopting a holistic approach that considers economic, social, and environmental aspects is deemed highly relevant to balance interests and achieve activity sustainability. Above all, the pursuit of improved partnership relations, solid economic outcomes, and well-managed generational renewal can be paths towards the continuity and success of the activity.

CONCLUSIONS

The aim of this study was to analyze the profile of rural producers involved in the integration system and associated aspects within the economic, social, and environmental dimensions of the activity. The main conclusion of the study entails that the profile of rural producers engaged in the integration system of poultry and pig production is strongly linked to economic, social, and environmental factors. Through cluster analysis, four distinct groups of producers were identified, each with specific characteristics related to age, family generation, education, profitability, satisfaction, and environmental impacts.

The diversity within these groups indicates that various factors influence the producers' attitudes towards integration activities in the studied region. Similar findings have been identified in previous studies conducted in different regions, suggesting a potential convergence in terms of production characteristics within the integration system, irrespective of location. To ensure the long-term sustainability of this activity, it is crucial to adopt responsible production practices, invest in technologies that mitigate negative impacts, and promote public policies encouraging sustainable practices, balancing economic, social, and environmental aspects in agricultural production.

The practical contribution of this study lies in providing insights for stakeholders involved in the integration system, such as integrating companies, regulatory bodies, governments, and producers. A detailed understanding of producers' profiles and the factors influencing their satisfaction, profitability, and future perspectives can aid in making strategic decisions to improve the relationship between the parties and ensure system sustainability through effective public policies and corporate strategies. From a theoretical perspective, this study contributes to understanding the interconnection between economic, social, and environmental dimensions in integration activity. It underscores the importance of considering factors beyond the economic ones to comprehend the dynamics of this activity and how they are interrelated.

The findings of the study have significant managerial implications for integrating companies and producers. Companies can use this profile analysis to tailor their support strategies for producers, considering satisfaction, engagement, and specific challenges of each group. Understanding environmental concerns and motivations of producers can also enable better alignment of practices

with expectations, as integrating companies can adjust their policies to better meet different needs and concerns of producers, leading to a more sustainable and mutually beneficial relationship.

Some limitations of the study include the representativeness of the sample, which focused on a specific region, and the quantitative nature of the research, which may not capture all producers' perceptions. Additionally, cluster analysis is sensitive to variable selection and the researchers' choice of the number of clusters, introducing a degree of subjectivity.

Certainly, there are several recommendations for future studies in the agribusiness, management, and integration system context, with the aim of generating applied solutions for poultry and pig production systems: i) conduct longitudinal research to track the evolution of producers' profiles over time; ii) supplement quantitative studies with qualitative analyses, such as in-depth interviews and focus groups; iii) investigate the impact of government policies and integrating companies' practices on producers' motivation and decisions; iv) explore technological solutions that can assist producers in addressing challenges; and v) develop specific training programs for the different groups of identified producers. These recommendations can contribute to generating more in-depth knowledge, practical insights, and applied solutions for the poultry and pig production system, thereby enhancing sustainability and success in the agribusiness sector.

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