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Food Supply Chain Traceability: A Multiple Case Study from Alto Tietê Region, Brazil †

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Abstract: Traceability is one way to ensure food supply chain transparency. However, when food is produced by family farmers, especially in communities with low levels of education and a lack of TI infrastructure, traceability becomes a major challenge. This article verified the adequacy of the family farmer to the traceability of the food production chain through the application of a multiple case study in Alto Tietê region, Brazil. The results showed that most farmers have an incomplete elementary education (55%), largely work alone in production, and are unable to carry out traceability due to the lack of pesticide registration, which makes implementation unfeasible even if the community has IT infrastructure.

Keywords: food safety; production control; process quality; supply chain transparency

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1. Introduction

In the past, the pesticide system was a great innovation for agricultural production. Nowadays, it is a health and environmental problem to food supply chain transparency, mainly in countries that do not have a food supply chain traceability structure. Traceability is a priority to increase awareness and prevent food contamination [1]. In Brazil, vegetable production is characterized by the intensive type of pesticide that is applied, and in many cases, the amount of pesticide detected is higher than the legal limits [2]. In 2018, the Brazilian government instructed the restructuring of the food supply chain, in order to apply traceability in the production process [3,4]. However, Alto Tietê family farmers were not prepared to meet the government's requirements.

The main source of Brazilian food production is from family farms who supply the food market. They represent 77% of all agriculture companies and almost 67% of the people employed in agriculture are from family farms [5]. Family farms are defined as rural activity that is managed by relatives; the production is carried out by the owners but the capital belongs to the family that reside on the rural properties [6].

In the Alto Tietê Region, among 12 cities, Mogi das Cruzes is highlighted due to its major number of rural properties (1379). Regarding the schooling of farmers, it is evidenced that almost 3% never attended school, 52% studied up to elementary school, 28% studied up to high school, and 17% studied up to college level [7].

Brazilian vegetable production faces many challenges related to pest control and the wellbeing of family farmers, such as: the social status of rural people, low level of education, lack of awareness about safety when working in the field, lack of rural infrastructure and digital inclusion, and people not following good production and pesticide practice, associated with a lack of inspection and a high degree of bureaucracy in government processes. Thus, to guarantee the quality of food, control of the pesticide system is necessary

to meet the requirements of market and law, in order to ensure that people only consume fresh products that are free from chemical residues. Astill et al. warned of the number of hospitalizations in the USA due to foodborne illness [8].

Aung and Chang proposed that traceability is one way to meet legal requirements, and is an effective system for monitoring the food supply chain [9]. Thus, the traceability system offers several advantages and provides information that contributes to food supply chain visibility [1]. Therefore, in this context, traceability's aggregate value to the supply chain, due to increasing its credibility, improves consumer perceptions of quality and guarantees food safety.

In this study, we highlighted the research question: RQ—what is the impact of socioeconomic conditions on the adaptation of family farmers to the food chain traceability system? In the context of real Brazilian family farm conditions, this paper aims to investigate the adequacy of the family farmer to the traceability process to guarantee the food supply chain transparency from farm to fork.

2. Materials and Methods

To achieve this, we conducted a multiple case study with family farmers using the questionnaire that was approved by the Ethics Committee (No. 4.570.174/2021). The questionnaire was structured in three parts: the first related to the social economics aspect [SEA] with 8 closed questions, the second related to the productions process aspect [PPA] with 9 closed questions, and the last part related to the food supply chain's traceability and the government's requirements [FSCT] composed by 18 open-closed questions, and this total 8 questions focus on property with traceability system.

The data were collected in March 2021 following the design of an interview, Figure 1.

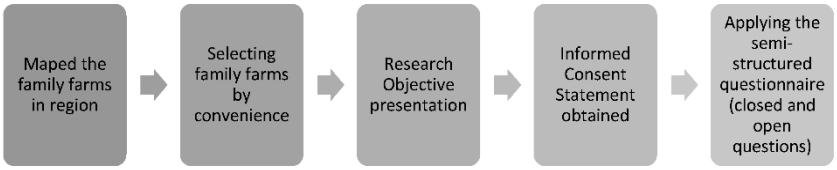

Figure 1. Steps of data collection procedure.

Considering the interview design, all family farmers gave answers about SEA and PPA, and their part in FSCT if the property used the traceability system. The farmers that agreed to participate as a volunteer in the research were provided an explanation about the research objective, risks and benefits.

Data Analysis

We carried out the description statistics to explore the table and graphic results using a frequency distribution table and a proportionality study. To answer the RQ, we investigated the association among socioeconomic variables and traceability system adequation in family farmers' property, using the Chi-squared test (χ^2), Equation (1) [10].

$$\chi^2 = \sum_{i=1}^{I} \sum_{j=1}^{J} \frac{(Oij - Eij)^2}{Eij}, \quad (1)$$

where, I = number of variable categories of X; J = number of variable categories of Y; Oij = number of observations (i = categories of variable X; j = categories of variable Y); Eij = expected frequency of observations (i = categories of variable X; j = categories of variable Y). In this analysis, we applied the 95% confidence interval and the p-value = 0.05.

3. Results

Nine family farmers participated in the research and the results mainly showed that most farmers did not finish elementary school (55%), which could affect the process of

applying traceability, Table 1. Our results are similar with the previous literature review [7]. We did not find an association among level of education and family income (χ^2 = 6.3; p = 0.09789), but we noted that farmers with an incomplete elementary education had a family income of around 4 to 5 basic salary and farmers with a high school level education or above had a 7 to 8 basic salary.

Table 1. Highlighted results on socioeconomic variables, values in %.

Socioeconomics Variables	Highlighted Results	Values in %
Gender	Male	80
Age	Above 46 years old	55
School	Elementary school	55
Family income	From 3 to 7 basic salary	67
Family size	From 3 to 4 people	55
Legal condition of farmer	Independent farmer	67
Work experience in years	Above 31	55
Production system	Conventional production	89
People in family working on farm	No, just family members	67

We found an association between farmer work experience and family income (χ^2 = 13.5; $p < 0.05$), and we observed that the majority had an income that was above 3 basic salary and over 21 years of agriculture work experience. Considering the production process, 89% of farmers applying the conventional techniques said they did not receive any technical assistance from government. Analyzing the agriculture pesticide applied by farmers, such as fungicide, insecticide and/or herbicide, we did not find association among farmer work experience in agriculture and the type of pesticide applied, Table 2.

Table 2. Distribution of farmer work experience in agriculture and type of pesticide applied (values in %).

Farmer Work Experience in Years	Biological	Organic	Chemical
From 11 to 20	7.14		14.28
From 21 to 30		7.14	7.14
From 31 to 40		7.14	14.28
Above 41		21.42	21.42

(χ^2 = 6.73; p = 0.3467).

From a total of nine farmers, one farm showed more technological use and capacity to grow agricultural produce and had family members working on the farm together with other family members, with the use of tractors, seeders and fertilizers, unlike the others that used only tractors.

Local Farmers and Traceability System Implementation

Local farmers produce many kinds of fresh food, such as onion, parsley, cabbage, potato, carrot, lettuce, radish, chard, kale, endive, mustard, coriander, and so on. Most farmers work alone in agricultural production and sometimes family members help them with production procedures. Thus, the farmers do not have free time to dedicate to other activities, such as education, training and practicing a hobby.

Farmers informed us that they were interested in learning new things, such as computer use and other tools to help them to control and manage the agricultural production. Some farmers participated in the Rural Association of the Jundiapeba Farmers, and Re-gion [APROJUR], where once a week, farmers meet to discuss agricultural subjects, such as traceability systems, digital inclusion, new tools of production control, etc. Our results evidenced that all farms have internet access, however 88% of farmers did not have basic computer knowledge.

Regarding the traceability system implementation, technological tools are essential for a successful information control and production process. Despite all famers having knowledge about the law of traceability obligation [3,4], just one farmer applied traceability, but in 1% of all production areas—in another words, 99% of production was not traced.

Considering the question about the criteria to comply with the law and the difficulty of this, Figure 2, we noted that the majority of farms have the conditions to provide the information technological infrastructure [TI], pesticide control and documentation to supply registration and information, but farmers highlighted the extreme difficulty of training people to work in agricultural production, provide food identification and data capture, and get involved in exchange along the supply chain. We also observed that 50% were worried about the return of capital investment with regards traceability system implementation.

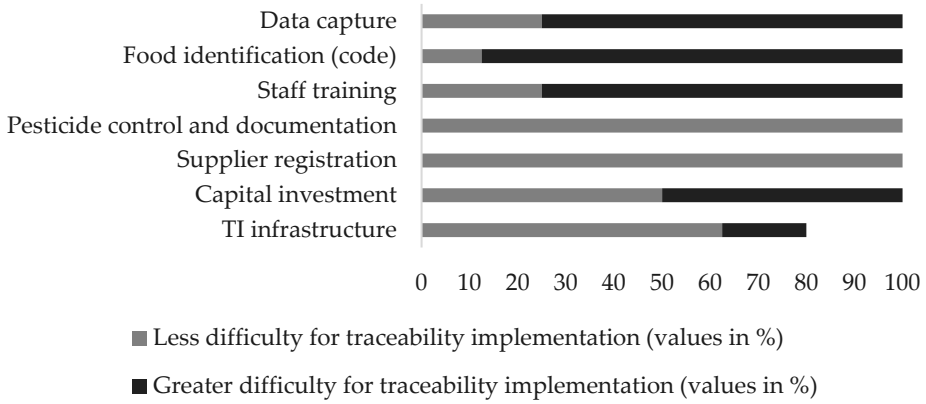

Figure 2. Degree of difficulty of traceability system implementation.

According to the farmer that applied traceability in 1% of production, the greatest difficulty of traceability system implementation is related to "our legislation, because there is no registration of all the pesticide used in agricultural production, such as for the cultivation of onion, parsley, coriander, basil and mint". On the other hand, there are pesticides that could be applied to groups of vegetables from the same family, such as cabbage, and cauliflower, but this does not have the same effect due to not matching the right vegetable with the right product.

We also did not find an association between education level and traceability criteria implementation, but we did note an association among traceability criteria implementation and farmers' perception ($p < 0.05$), Figure 3.

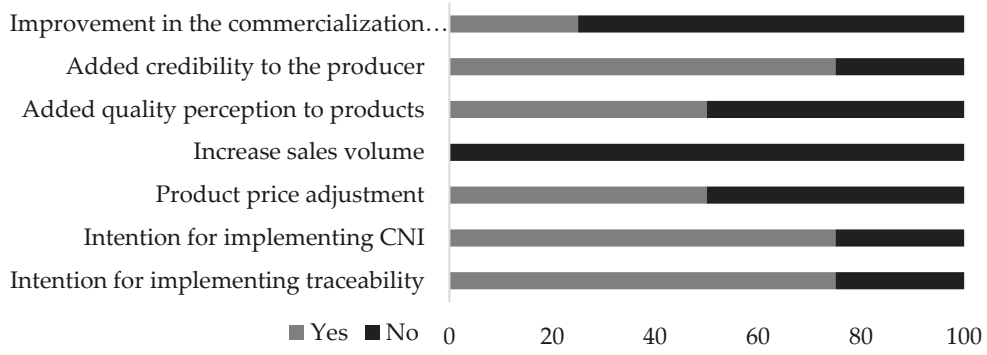

Figure 3. Traceability criteria implementation and farmers perception. $\chi^2 = 16.0$; $p = 0.0137$; CNI = Brazilian traceability law.

Most farmers agreed with the statement that traceability is important to the vegetable supply chain, however, they did not have "faith" in the procedure and did not see the

benefits related to adjusted sale price, an increase in sales volume or improvement to the process, due to the actual Brazilian sales design of fresh food that included intermediaries in the supply chain.

Local farmers were emphatic in answering that it is the responsibility of the state, since the laws are in their hands, and they must provide support, whether social, technical legal or financial. One of the participating farmers replied: "Yes, public management should be the first to provide inputs and infrastructure for adaptation", while another reported: "There are difficulties in relation to the high amounts paid in inputs for production, and with traceability it would be more an addition that would not be transferred".

4. Discussion

Brazilian agriculture has been facing a depopulation process over the years due to hard rural work and low pay (dissatisfaction), as well as young people moving to cities in search of better living conditions, however, this threatens the succession of the family farmer business [11]. Fonseca et al. and Kageyama contributed to the discussion by elucidating that this dissatisfaction is related to the rural socioeconomic factors, such as education and family income, and both could help farmers to invest in the production system and use management strategies to comply with government and market requirements [12,13].

In addition, Brazilian production in rural areas faces many challenges regarding agricultural activities, such as the hard work every day of production with few people, technology access, the cost of raw-material, and commercialization due to the low price of commodities that impact on family income [11]. These are critical social problems that could affect the family farmer's ability to adopt traceability. According to Astill et al., to complete a traceability system, sixteen drivers should be considered by the food supply chain, such as food safety and quality, as well as food waste or loss, information quality, health and wellbeing standards, regulation/certification, and above all, consumer awareness, market protection and competitive advantage [8]. Thus, it is not a simple task for family farms without the right structure and support.

Patidar et al. highlighted that traceability provides information about food across each process of the supply chain, including procurement, production and distribution [1]. The authors explained that a basic traceability system should consider three components: data identification, a database management system, and data exchange among actors of the supply chain [1]. Astill et al. stated that this information must be available from origin to consumers and beyond, in supply chains including many aspects of agricultural procedures, transport, packaging and storage conditions [8].

There are a few practices involving family farmers and technology application using control and technical monitoring which cause a series of obstacles in the implementation of traceability systems [14]. Thus, knowing the real condition of Brazilian family farmers, traceability could become a barrier to entry for producers in the market if they are unable to adapt, due to the cost of the infrastructure that is needed to carry out the monitoring and training of the personnel involved in the activity [14]. A dangerous way is contribution to the formation of a parallel market for non-traceable and uncontrolled food

In addition, the difficulty of implementing a traceability systems will cause family farmers to resist new technology and good production practices [15]. Results from Carvalho research revealed that 24% of farmers have access to the Internet in their homes or at the Rural Association [16]. In contrast to our results, all the farmers that contributed to this paper had Internet access at home but did not have the knowledge to use it.

In general, the family farmers agreed that a traceability system is important to the food control and monitoring process, but in current conditions it does not function as well as projected, due to: (1) lack of pesticide registration to use in agricultural production; (2) current commercialization design that allow lots of products to merge, and this is inconsistent with the traceability premise; (3) lack of government support and training people; (4) high investment by family farmers and no return payment expected—in other words, the cost is not transferred to the market.

In conclusion, traceability in the Alto Tietê food supply chain will only be possible when the government creates a structure to create an adequate pesticide system, clarify traceability law, and provide the training and support to rural families involved in the food supply chain. Despite not finding an association with education level and the criteria of traceability system implementation, 55% of the family farmers studied up to elementary school level and most did not have the skills to work with computers in order to register the production information.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/IOCAG2022-12176/s1.

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Data Availability Statement: Not applicable.

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