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# Assessment of the dairy chain sustainability through best management practices Brazil's programs

## Avaliação da sustentabilidade da cadeia de produção do leite pelos programas de boas práticas do Brasil

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**Abstract**: This study aimed to assess six primary Best Management Practices programs implemented in Brazil concerning the sustainability of the dairy chain. This assessment was based on the measures outlined in the FAO & IDF Guide to Good Dairy Farming Practices. The six programs analyzed included the Safe Food Program, the Good Practices for Sustainability, the Good Practices on the Farm, the Quality Milk Production, the Educampo, and the Full Bucket programs. The characteristics of each program were categorized into six areas: animal health, milking hygiene, nutrition (food and water), animal welfare, environment, and socioeconomic management. Each category was further divided into subcategories. Qualitative data from the programs were converted into quantitative responses and subjected to statistical analysis. The results revealed that the Safe Food Program was the only one that demonstrated a strong alignment with the Guide across all categories. The Good Practices for Sustainability Program and the Good Practices on the Farm Program exhibited medium to high correspondence with the Guide. However, they both require significant improvements in animal welfare. Additionally, the Good Practices on the Farm Program needs enhancements in the environmental management category. The Quality Milk Production Program showed low alignment with the Guide, indicating a need for extensive improvements in nutrition (food and water), animal welfare, environmental practices, and socioeconomic management. The Educampo and Full Bucket programs exhibited very low correspondence with the Guide, requiring substantial enhancements in all categories except for socioeconomic management. Consequently, these two programs are best utilized as supplementary initiatives alongside more established programs, such as the Safe Food Program, the Good Practices for Sustainability Program, or the Good Practices on the Farm Program, effectively addressing important socioeconomic management gaps.

**Keywords:** FAO; milk production; milk chain; sustainability indicators.

**Resumo:** A correspondência entre os seis principais programas de Melhores Práticas de Manejo (MPM) utilizados no Brasil para promover a sustentabilidade da cadeia leiteira foi avaliada com base nas diretrizes contidas no Guia de Boas Práticas de Produção de Leite da FAO e IDF. Os programas analisados foram: Programa Alimentação Segura, Programa Boas Práticas para Sustentabilidade, Programa Boas Práticas na Fazenda, Programa de Produção de Leite de Qualidade, Projeto Educampo e Projeto Balde Cheio. As características de cada programa foram organizadas em seis áreas principais: saúde animal, higiene da ordenha, nutrição (alimentação e água), bem-estar animal, meio ambiente e gestão socioeconômica. Cada uma dessas áreas foi subdividida em subáreas. Os dados qualitativos obtidos foram transformados em respostas quantitativas e submetidos a uma análise estatística. Os resultados mostraram que o Programa Alimentação Segura é o único que apresentou elevada correspondência com o Guia em todas as áreas. Os programas Boas Práticas para Sustentabilidade e Boas Práticas na Fazenda demonstraram uma correspondência média a alta, embora ambos necessitem de ajustes significativos na área de bem-estar animal. O Programa Boas Práticas na Fazenda também requer melhorias na gestão ambiental. Por outro lado, o Programa de Produção de Leite de Qualidade teve baixa correspondência com o Guia, necessitando de várias melhorias nas áreas de nutrição (alimentação e água), bem-estar animal, meio ambiente e gestão socioeconômica. Os Projetos Educampo e Balde Cheio apresentaram uma correspondência muito baixa, demandando intensas melhorias em todas as áreas, exceto na gestão socioeconômica. Diante disso, recomenda-se que esses projetos sejam implementados de maneira concomitante e complementar a programas mais robustos, como o Programa Alimentação Segura, Boas Práticas para Sustentabilidade ou Boas Práticas na Fazenda, que podem preencher lacunas importantes na gestão socioeconômica.

**Palavras-chave:** cadeia de laticínios; guia da FAO e IDF; indicadores de sustentabilidade; produção de leite.

## 1. Introduction

Brazil ranks as the world's third-largest milk producer, confirming its robust dairy industry. Recently, however, the sector has faced significant changes due to producers' growing dissatisfaction with competition from imported milk products [1]. While milk production occurs nationwide [2,3], it is mainly concentrated in the southeast and southern states, where a few significant agro-industries lead the way. This concentration showcases the potential for innovation and quality that can elevate Brazil's dairy sector to new heights.

The quality of Brazilian milk presents an opportunity for improvement and is recognized as a national challenge [4,5]. Many dairy farms could benefit from enhanced technical assistance and the adoption of appropriate technologies and knowledge, even among the larger, more productive producers [6]. Regardless of farm size, it's required to cultivate sustainable production systems, integrating efficiency with increased productivity and profitability. At the same time, these systems should prioritize the health and welfare of humans and animals while safeguarding the environment. Emphasizing these categories can lead to significant advancements in the dairy industry.

Dairy farms must implement suitable production and management practices to ensure long-term success. The Food and Agriculture Organization of the United Nations (FAO) and the International Dairy Federation (IDF) have developed a set of Best Management Practices (BMP). These practices are designed to enhance milk quality and promote the sustainability of dairy farming systems. By following these guidelines, farmers and the production chain players can secure long-term economic, social, and environmental benefits in milk production. Additionally, these practices can effectively inform better public policies and private actions, facilitating the appropriate implementation of best management techniques. This study aimed to assess the relationship between the leading BMP programs implemented in dairy farms in Brazil and the recommendations outlined in the BMP Guide by the FAO & IDF Guide.

## 2. Material and methods

Approval from the Human Research Ethics Committees was unnecessary for this study, as all the collected data belongs to programs or institutions rather than individuals as private persons.

### 2.1 Data

Dairy farming-related institutions provided the data utilized in the present study. The institutions included in this study were National Service for Rural Learning (SENAR), Brazilian Service for Support for Micro and Small Businesses (SEBRAE), National Service for Industrial Learning (SENAI), Quality Consultants of New Zealand América Latina Ltda (QCONZ), Embrapa Gado de Leite, Embrapa Clima Temperado, Embrapa Pecuária Sudeste, Program for the development of Dairy Production of the Universidade Federal de Viçosa (PDPL/UFV), Federations of Agriculture and Animal Production and Secretaries of Agriculture, Animal Production and Supply of the States of Minas Gerais, Goiás, Paraná, Santa Catarina, and Rio Grande do Sul (States with most significant Milk Production). In addition, data from the following private milk companies were included in the present study: DPA/Nestlé - Fonterra®, Danone®, CCPR/Itambé®, and Laticínios Bela Vista/Piracanjuba®.

The six main programs of BMP implemented in dairy farming in Brazil evaluated in this study were the Safe Food Program (Embrapa-SENAI-SEBRAE), Good Practices for the Sustainability Program (Unilever® and Piracanjuba®), Good Practices on the Farm program (DPA/Nestlé and Fonterra®), Quality Milk Production Program (SENAR-SEBRAE), Educampo (SEBRAE), and Full-Bucket Project from Embrapa Pecuária Sudeste. All the records were organized into six categories: animal health, milking hygiene, nutrition (food and water), animal welfare, environment, and socio-economic management. Each category was further subdivided into subcategories, and various factors were assessed within each subcategory (Table 1).

Each category and subcategory are based on the similarities identified in the FAO & IDF Guide. An organized database has been created to standardize the data. The data were analyzed according to specific criteria derived from empirical research while conforming to the current classifications outlined in the FAO & IDF Guide. The data were converted into a discrete scale: 1.00 indicates full compliance, 0.75 represents high partial compliance, 0.50

denotes median partial compliance, 0.25 indicates low partial compliance, 0 signifies non-compliance, and -1.00 denotes inapplicability for each characteristic of the evaluated programs. These scores are based on the qualitative data: ease of implementation, time required for deployment, implementation cost, monthly maintenance cost, evaluation of programs by milk producers and the dairy industry, stimulation of additional payments for milk quality, adherence to good practices in the transportation of milk and dairy products, integration between producers and dairy companies, practical application and target audience priority, and adaptability to the FAO & IDF Guide.

**Table 1.** The categories and subcategories of Safe Food Program (Embrapa-SENAI-SEBRAE); Good Practices for Sustainability Program (Unilever®- Piracanjuba®); Good Practices on the Farm Program (DPA/Nestlé - Fonterra®); Quality Milk Production Program - Legal Milk (SENAR-SEBRAE); Educampo (SEBRAE); and Full Bucket Project (Embrapa Southeast Animal Production) Brazilian Dairy Best Management Programs assessed by FAO & IDF Guide [9].

| Category | Subcategory | Description |
|---|---|---|
| Animal Heath | 1 | Establish the herd with disease resistance |
| | 2 | Prevent entrance of diseases on the farm |
| | 3 | Establish an effective program of health management of the herd |
| | 4 | Using chemicals and veterinary medicines |
| Milking Hygiene | 1 | Ensure that the milking routine does not injure animals or introduce contaminants into milk |
| | 2 | Ensure that milking is carried out hygienically |
| | 3 | Ensure that milk is handled correctly after milking |
| Nutrition | 1 | Ensure the supply of food and water from sustainable sources |
| | 2 | Ensure food and water to animals in adequate quantity and quality |
| | 3 | Control food storage conditions |
| | 4 | Ensure traceability of food purchased by the farm |
| Animal Welfare | 1 | Ensure that animals are free of thirst, hunger and malnutrition |
| | 2 | Ensure that animals are free of discomfort |
| | 3 | Ensure that animals are free of pain, injury and disease |
| | 4 | Ensure that animals are free of fear |
| | 5 | Promote conditions for animals to follow normal patterns of behavior |
| Environment Management | 1 | Implement an environmentally sustainable production system |
| | 2 | Appropriate waste treatment system. |
| | 3 | Ensure that milk production procedures had no adverse effect on the environment |
| Socio-economic Management | 1 | Implement an effective and responsible program of people management |
| | 2 | Ensure that the tasks are carried out safely and competently |
| | 3 | Manage the farm to ensure its financial viability |

## 2.2 Analysis

The descriptive statistics were performed using PROC FREQ and PROC CORRESP from SAS® software version 9.4 (Statistical Analysis System, Cary, North Carolina). The frequency analysis confirmed the percentage of scores for the BMP measures recommended by the FAO & IDF Guidelines in each of the six evaluated programs. Based on the frequency results, correspondence analysis was conducted to evaluate the spatial relationships of distance between each program and concerning the original recommendations from the FAO & IDF Guide.

## 3. Results

It was possible to find associations between the BMP programs that better aligned with the FAO & IDF Guide. Table 2 presents scores by subcategory, while Tables 3 and 4 detail the category where recommendations were not met. Among the examined categories, safe food and good practices for sustainability programs were closely aligned with the FAO & IDF Guide, fully complying with the guide's requirements. Conversely, Educampo and Full-Bucket programs showed a minor alignment. The good practices of the farm and quality milk production programs partially met the criteria. Several exceptions were noted; for instance, in milking hygiene, good practices of the farm program performed comparably to the safe food program, whereas the quality milk production program did not meet the standards for animal welfare.

### 3.1 Health

The rates of animal health non-compliance observed in the Educampo and Full-Bucket programs indicate low adherence to measures designed to prevent disease entry onto farms and inadequate use of chemicals and veterinary medicines based on recommended technical guidelines. These programs had 75% and 62.5% compliance ratings, respectively, for establishing effective herd health management programs. Consequently, disease resistance must be addressed for the shortcomings evident in these programs.

The Quality Milk Production Program demonstrated intermediate compliance, showing a lower level of adherence to animal health measures compared to the guidelines set by FAO & IDF. This program exhibited a non-compliance rate of 66.7% in subcategories 1 and 2 and a 25% non-compliance rate in subcategories 3 and 4. There was a 50% intermediate compliance rate in subcategories 3 and 4, 33.3% in subcategories 1, and partial compliance (25%) in this subcategory. Among these, subcategory 2 had the most significant gaps, showing 0% compliance and only 33.3% partial compliance with the recommended measures.

In contrast, the Safe Food Program, Good Practices for Sustainability Program, and Good Practices on the Farm Program exhibited high compliance levels in their respective categories. They achieved 100% compliance with the criteria outlined for subcategory 4. The Safe Food Program and the Good Practices on the Farm Program also received 100% compliance in subcategory 3, while the Good Practices for Sustainability Program attained 75%. Thus, the weaknesses in these programs arose primarily in subcategories 1 and 2. Specifically, the Good Practices on the Farm Program and the Good Practices for Sustainability Program fell short compared to the Safe Food Program, recording 66.7% non-compliance in subcategories 1 and 50% in subcategories 2. The main gaps in these programs were highlighted by the low partial compliance of 33.33% in subcategory 1, notably a concerning 16.67% in subcategory 2.

### 3.2 Milk hygiene

In each program's evaluation, three milking hygiene subcategories were assessed: the milking routine does not injure animals or introduce contaminants into milk, is carried out hygienically, and is handled correctly after milking.

**Table 2.** Scores of the Brazilian dairy farm Best Management Programs (BMP).

| | Program's Score | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Full Bucket | | | | | | Educampo | | | | FAO[1] | Quality Milk Production | | | | | | Good Practices on the Farm | | | | | | Safe Food | | | | | | Good Practices for Sustainability | | | | | |
| Category and Sub_category | -1 | 0 | 0.25 | 0.5 | 0.75 | 1 | -1 | 0 | 0.5 | 1 | 1 | -1 | 0 | 0.25 | 0.5 | 0.75 | 1 | -1 | 0 | 0.25 | 0.5 | 0.75 | 1 | -1 | 0 | 0.25 | 0.5 | 0.75 | 1 | -1 | 0 | 0.25 | 0.5 | 0.75 | 1 |
| Environment | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| No adverse effect | | 2 | 1 | | | | 3 | | | | 3 | 3 | | | | | | | 1 | | | 2 | | | | | | | 3 | | | | | | 3 |
| Residues | | 2 | | | | | 2 | | | | 2 | 2 | | | | | | | | | 1 | 1 | | | | | | | 2 | | | | | | 2 |
| Sustainability | | 2 | | | | 1 | 4 | 6 | | 1 | | 7 | 7 | | | | | | 3 | 1 | | | 3 | | 3 | 1 | | | 3 | | | | 1 | | 6 |
| Health | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Entrance | | 7 | | | | | | 7 | | | 7 | | 5 | 2 | | | | | 3 | 1 | 1 | | 2 | | 1 | 1 | 1 | | 4 | | 3 | 1 | 1 | | 2 |
| Establish | | | 1 | 1 | | 1 | | | | 3 | 3 | | 2 | | | | 1 | | 2 | | | | 1 | | | 1 | | 1 | 1 | | 2 | | | | 1 |
| Inputs | | 4 | | | | | | 4 | | | 4 | | 1 | | 1 | | 2 | | | | | | 4 | | | | | | 4 | | | | | | 4 |
| Program | | 8 | | 2 | | 1 | | 9 | | 2 | 11 | | 2 | 1 | 1 | 1 | 6 | | 1 | | | | 10 | | 1 | | | | 10 | | 4 | | | | 7 |
| Milking | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Hygiene | 6 | | | | | | 6 | | | | 6 | | | 1 | | | 5 | | | | | | 6 | | | | | | 6 | | | | | | 6 |
| Routine | 18 | | | | | | 18 | | | | 18 | | 3 | 1 | 1 | 2 | 11 | | | | | 3 | 15 | | | | | 1 | 17 | | 2 | | | 1 | 15 |
| Handling | 15 | | | | | | 15 | | | | 15 | | 4 | | 2 | 3 | 6 | | | | | 1 | 14 | | 1 | | | 1 | 13 | | 2 | 1 | | | 12 |
| Nutrition | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Origin | | 2 | | | | | | 2 | | | 2 | | 2 | | | | | | 1 | | | | 1 | | | | | | 2 | | 1 | | | 1 | |
| Quality | | 4 | 1 | | | 1 | | 5 | | 1 | 6 | | 4 | | 2 | | | | | 1 | | 2 | 3 | | | | | | 6 | | 1 | | | | 5 |
| Storage | | 3 | | | | | | 3 | | | 3 | | 3 | | | | | | 1 | | | | 2 | | | | | | 3 | | 1 | | | | 2 |
| Traceability | | 1 | | | | 2 | | 1 | | 2 | 3 | | 2 | | 1 | | | | 3 | | | | | | 1 | | | 1 | 1 | | 3 | | | | |
| Socio-economic | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Finance | | | | 1 | 1 | 4 | | | | 6 | 6 | 4 | | | 1 | | 1 | 3 | | | 2 | | 1 | 3 | | | 2 | | 1 | 2 | 1 | 1 | | 1 | 1 |
| Tasks | | 2 | | 1 | 1 | 2 | | 2 | | 4 | 6 | 6 | | | | | | | | | | | 6 | | | | | | 6 | | 1 | | | | 5 |
| Workers | | 4 | | | | | | 4 | | | 4 | 4 | | | | | | | | | | | 4 | | | | | | 4 | | | | | | 4 |
| Welfare | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Behaviour | | 1 | | | | | 1 | | | | 1 | | 1 | | | | | | | | | 1 | | | | | | | 1 | | | 2 | | | |
| Comfort | | 5 | 1 | | | | 6 | | | | 6 | | 5 | 1 | | | | | 2 | | | 1 | 3 | | 1 | | | | 5 | | 1 | | | 2 | 3 |
| Fear | | 3 | | | | | 3 | | | | 3 | | 2 | 1 | | | | | 1 | | | | 2 | | | | | 1 | 2 | | 1 | | | 2 | 2 |
| Hunger | | 1 | 1 | | | 2 | | 2 | | 2 | 4 | | 4 | | | | | | 1 | | | 2 | 1 | | | | | 1 | 3 | | 2 | | | | 2 |
| Pain | | 8 | | 1 | | | 8 | | | 1 | 9 | | 7 | | | | 2 | | 4 | 1 | | 1 | 3 | | 3 | | | 1 | 5 | | 3 | 1 | 1 | | 4 |

[1]*FAO & IDF Guide*[9]

**Table 3.** Schematic formulations of correspondence for the ideal categories and subcategories of each Program concerning the measures suggested in the FAO & IDF Guide[9].

| Category | Subcategory | Schematic Formulations of Correspondence |
|---|---|---|
| Animal Health | | FAO > A > C > B > D > E > F |
| | 1 | FAO ≅ E > A ≅ F > B ≅ C ≅ D |
| | 2 | FAO > A > B ≅ C > E ≅ F≅ D |
| | 3 | FAO ≅ A ≅ C > B > D > E > F |
| | 4 | FAO ≅ A ≅ B ≅ C > D > E ≅ F |
| Milking Hygiene | | FAO ≅ A > B ≅ C > D > E ≅ F |
| | 1 | FAO ≅ A ≅ D > B ≅ C > E ≅ F |
| | 2 | FAO ≅ A ≅ B ≅ C > D > E ≅ F |
| | 3 | FAO ≅ A ≅ B ≅ C > D > E ≅ F |
| Nutrition | | FAO > A > B > C > F > E > D |
| | 1 | FAO > E ≅ F > A > D > B ≅ C |
| | 2 | FAO ≅ A > B > C > F > E > D |
| | 3 | FAO ≅ A > B ≅ C > D ≅ E ≅ F |
| | 4 | FAO ≅ A > C > B > D ≅ E ≅ F |
| Animal Welfare | | FAO > A > C > B > F > D > E |
| | 1 | FAO > A > F > C > B ≅ E > D |
| | 2 | FAO > A > B > C > D ≅ F > E |
| | 3 | FAO > A ≅ B > C > D > F > E |
| | 4 | FAO > A > C > B > F > D > E |
| | 5 | FAO ≅ A ≅ C ≅ B ≅ F >D > E |
| Environment Management | | FAO > B > A > C > F > D ≅ E |
| | 1 | FAO > B > F > A ≅ C > D ≅ E |
| | 2 | FAO ≅ A ≅ B ≅ D ≅ E > C > F |
| | 3 | FAO ≅ B > A > C > F > D ≅ E |
| Socio-economic Management | | FAO > B > A ≅ C > E > F > D |
| | 1 | FAO ≅ A ≅ B ≅ C > E ≅ F > D |
| | 2 | FAO ≅ A ≅ B ≅ C > E > F > D |
| | 3 | FAO ≅ E > F > A ≅ B ≅ C ≅ D |

*A: Safe food Program (Embrapa-SENAI-SEBRAE); B: Good Practices for Sustainability Program (Unilever®- Piracanjuba®); C: Good Practices on the Farm Program (DPA/Nestlé - Fonterra®); D: Quality Milk Production Program - Legal Milk (SENAR-SEBRAE); E: Educampo (SEBRAE); and F: Full-Bucket Project (Embrapa Southeast Animal Production); acronyms for subcategory in Table 1.*

The Educampo and the Full-Bucket programs demonstrated 100% non-compliance with the standards, failing to ensure that the milking routine does not harm animals or introduce contaminants into the milk. They also did not properly carry out hygienic milking practices or handle the milk correctly after milking. In contrast, the Quality Milk Production Program showed intermediate compliance with milking hygiene measures, achieving 100% compliance in subcategory 1 and 75% compliance in subcategory 2. Additionally, this program exhibited 80% compliance with the standards in subcategory 3.

The Safe Food Program, Good Practices for Sustainability Program, and Good Practices on the Farm Program achieved 100% compliance in subcategories 2 and 3. The Safe Food Program also attained this level of compliance in subcategory 1. The Good Practices for Sustainability Program and Good Practices on the Farm Program scored 83.3% compliance in subcategory 1, with an additional 16.7% indicating high partial compliance.

**Table 4.** Subcategories with gaps (cross marks) in the sustainability of each evaluated in each program concerning the measures suggested in the FAO & IDF Guide [9].

| Category | Program's Sustainability Gaps | | | | | |
|---|---|---|---|---|---|---|
| | Safe food | Good Practices for Sustainability | Good Practices on the Farm | Quality Milk Production | Educampo | Full-Bucket |
| Animal Health | x | x | x | x | | |
| | | | | x | x | x |
| | | | | | x | x |
| | | | | | x | x |
| Milking Hygiene | x | x | x | | x | x |
| | | | | | x | x |
| | | | | x | x | x |
| Nutrition | x | x | x | x | x | x |
| | | | | x | x | x |
| | | | | x | x | x |
| | | | | x | x | x |
| Animal Welfare | x | x | x | x | x | x |
| | x | x | x | x | x | x |
| | x | x | x | x | x | x |
| | x | x | x | x | x | x |
| | | | | x | x | x |
| Environment Management | x | x | x | x | x | |
| | | | x | x | x | x |
| | | | x | x | x | x |
| Socio-economic Management | | | | x | x | x |
| | | | | x | | |
| | x | x | x | x | | |

Consequently, the gaps in compliance were specifically in subcategory 1; however, these gaps were of low intensity and only observed in the Good Practices for Sustainability Program and Good Practices on the Farm Program. The Safe Food Program fully complies with the measures set forth by the FAO & IDF.

## 3.3 Nutrition

The Quality Milk Production, Educampo, and Full-Bucket programs all showed 100% non-compliance in controlling food storage conditions and ensuring traceability of the food purchased by the farm. They also demonstrated non-compliance in providing food and water from sustainable sources and supplying adequate quantities and quality food and water to animals. Educampo and Full Bucket programs had intermediate compliance (66.7%) in ensuring food and water supply from sustainable sources. In contrast, the Quality Milk Production Program had 0% compliance across all subcategories. The non-compliance in all

four subcategories within the nutrition (food and water) category resulted in significant gaps, particularly in the Quality Milk Production Program and Programs E and Full Bucket Project.

Both the Good Practices for Sustainability Program and the Good Practices on the Farm Program reported 100% non-compliance in Subcategory 1, along with an additional 50% non-compliance in Subcategory 4 and 33.3% in Subcategory 3. However, both programs achieved intermediate compliance levels of 66.7% in subcategory 3 and 83.3% in subcategory 1. The Good Practices for Sustainability Program showed varying levels of partial compliance (between 0% and 50%) in subcategory 4, while the Good Practices on the Farm Program demonstrated 50% compliance. This reinforces the general similarities between the two programs in the nutrition (food and water) category. The main gaps for both programs were found in subcategory 1, with additional significant gaps noted in subcategories 4 and 3. Some compliance with the measures suggested by the FAO & IDF was observed in subcategory 2. Despite the high adherence to measures in this category, the Safe Food Program exhibited gaps in compliance with the standards recommended by the FAO & IDF, specifically showing 33.33% non-compliance in subcategory 1.

### 3.4 Welfare

The Educampo reported a complete lack of compliance in ensuring animals are free from discomfort and fear and promoting conditions that allow animals to exhibit standard behaviors. It achieved a compliance rate of 87.5% in ensuring animals are free from pain, injury, and disease. However, Program E demonstrated only intermediate compliance (50%) in subcategory 1, which focuses on ensuring that animals are free from thirst, hunger, and malnutrition. The high percentage of non-compliance, particularly the inability to apply the measures suggested by the FAO & IDF across all five subcategories, indicates significant gaps in compliance with this program's FAO & IDF guidelines.

The Full Bucket Project and the Quality Milk Production Program were 100% non-compliant in Subcategory 5. The Full Bucket Project also exhibited the same complete lack of compliance in Subcategory 4, while the Quality Milk Production Program had high non-compliance in Subcategories 1, 2, and 3. Although the Full Bucket Project achieved an intermediate compliance rate of 50% in Subcategory 1, the overall high non-compliance across all five subcategories indicates substantial gaps in animal welfare for both programs.

Conversely, the Good Practices on the Farm Program and the Good Practices for Sustainability Program showed median partial compliance in subcategories 1, 2, 3, and 4. Still, both programs displayed gaps in compliance with the FAO & IDF criteria in these subcategories due to several non-compliant indicators. Additionally, neither program achieved any compliance in subcategory 5; however, the Good Practices on the Farm Program did show a high rate of partial compliance overall. The Good Practices for Sustainability Program also exhibited median partial compliance, particularly in the subcategory with the fewest compliance gaps.

The Safe Food Program had the highest compliance rates among all programs. It achieved 100% compliance in Subcategory 5 and Subcategories 4 and 1, with an 83.33% compliance rate in Subcategory 2. The only category where the Safe Food Program faced significant compliance gaps was subcategory 3, which had a compliance rate of only 37.5%.

### 3.5 Environmental management

The Safe Food Program and the Good Practices for Sustainability Program achieved 100% compliance with appropriate waste treatment systems, ensuring that milk production procedures had no adverse environmental effects. The Good Practices for Sustainability Program also demonstrated 80% compliance in implementing an environmentally sustainable production system. However, in Subcategory 1, both the Good Practices for Sustainability Program and the Safe Food Program showed some gaps in compliance with the measures recommended by the FAO & IDF. Specifically, the Safe Food Program had a 40% non-compliance rate, while the Good Practices for Sustainability Program had a 20% non-compliance rate. In contrast, the Educampo and the Quality Milk Production programs exhibited 100% compliance with the FAO & IDF Guide across all three subcategories, indicating that the environmental management category needed evidence of compliance with these programs. Significant differences existed between the Good Practices on the Farm Program and the Full-Bucket Project across various subcategories. In Subcategory 3, the Good Practices on the Farm Program recorded 66.7% compliance, whereas the Full-Bucket Project showed complete non-compliance. Both programs had critical gaps in this subcategory, notably the Full-Bucket Project. In Subcategory 1, the Full-Bucket Project achieved 80% compliance. The Good Practices on the Farm Program demonstrated 40% non-compliance and 20% low partial compliance, indicating gaps in the Good Practices on the Farm Program. In Subcategory 2, the Full-Bucket Project had 100% non-compliance. The Good Practices on the Farm Program exhibited 50% high partial and 50% medium partial compliance, revealing gaps in the Full-Bucket Project.

### 3.6 Socio-economic management

The Safe Food Program, the Good Practices for Sustainability Program, and the Good Practices on the Farm Program all demonstrated 100% compliance with the criteria for effective and responsible people management, ensuring that tasks are carried out safely and competently. However, regarding managing farm financial viability, the Safe Food Program and Good Practices on the Farm Program showed 100% non-compliance, while Program B exhibited 66.7% non-compliance. This was the only subcategory where this grouping had critical gaps in compliance with the measures suggested by the FAO & IDF.

The Educampo and Full-Bucket programs, initially categorized by their intermediate behavior, exhibited similarities and differences when measuring compliance frequencies in each subcategory. As expected, the Quality Milk Production Program demonstrated 100% non-compliance across all three subcategories, indicating no evidence of compliance in the socio-economic management category.

When consolidating all categories, the Safe Food Program and the Good Practices for Sustainability Program aligned most with the FAO & IDF standards [9]. Nevertheless, some subcategories demonstrated compliance with the Guide, such as one animal health, one nutrition (food and water), and three socio-economic management, despite requiring more alignment overall.

In general, Program A can be considered the program with the fewest gaps in promoting sustainability, making it the most comprehensive and robust. It is followed by the Good Practices for Sustainability Program and the Good Practices on the Farm Program. In contrast, the Quality Milk Production, Educampo, and Full-Bucket programs revealed significant gaps in their sustainability efforts within the national dairy farming sector. Only 5 out of 22 subcategories (22.72%) showed essential gaps in the Safe Food Program. This program fully complied with the FAO & IDF Guide [9] regarding milking hygiene across all evaluated subcategorys. While the Good Practices for Sustainability Program and the Good Practices on the Farm Program were robust, they also revealed critical gaps in various assessed categories, particularly in animal health, milking hygiene, and nutrition (food and water). Furthermore, the Good Practices for Sustainability Program was the most comprehensive regarding environmental management. The Quality Milk Production Program was only compliant in subcategories 3 and 4 of animal health and subcategories 1 and 2 of milking hygiene. Programs E and the Full-Bucket Project, comparable and robust in socio-economic management, were only fully compliant in subcategories 1 of animal health and 2 and 3 of socio-economic management.

## 4. Discussion

The BMP programs implemented on Brazilian dairy farms showed variations in their alignment with the FAO & IDF's Guide of Good Practices in Milk Livestock [9]. The findings of this study indicate that all evaluated programs require some level of adjustment to enhance the sustainability of the dairy chain. It is important to account for the diverse milk production systems for optimal implementation of best management practices within the national dairy sector [1]. These different sectors of the industry require more tailored and appropriate public policies to support the overall sustainability of the dairy chain, from farm to consumer [7,11].

The Safe Food Program, Good Practices for Sustainability Program, and Good Practices on the Farm Program demonstrated more consistent, complete, and robust characteristics than those of other programs. However, improvements are still necessary for disease resistance measures, which should include ensuring the overall health of animals through proper nutrition, stress reduction, and maintaining an adequate population density [12].

These programs should also work towards securing a sustainable food and water supply while minimizing the environmental impacts of substances emitted by animals and extracted from the environment. Results indicate a need to ensure that animals are free from pain, injury, and disease. This aligns with the FAO's understanding that good animal welfare

practices involve preventing and treating diseases and injuries and alleviating pain, stress, and other harmful factors.

In addition to these enhancements, the Safe Food Program, Good Practices for Sustainability Program, and Good Practices on the Farm Program can be utilized to establish an environmentally sustainable production system [12]. This can involve integrating livestock and forests [13,14,15,16], recovering degraded pastureland, using legumes for nitrogen fixation, and adopting strategies to mitigate greenhouse gas emissions to promote low-carbon dairy farming [17]. Furthermore, these programs can enhance financial viability, as highlighted by Cervo et al. [18], who emphasized that even the smallest farms generate revenues and expenses and should be managed as rural enterprises with clear goals and objectives.

Moreover, the Good Practices for Sustainability Program and Good Practices on the Farm Program should be refined to ensure that milking routines do not harm animals or introduce contaminants into the milk. As De Silva et al. [10] supported, these programs should also better promote overall animal welfare by ensuring that animals are free from thirst, hunger, malnutrition, discomfort, pain, injury, disease, and fear [13,19]. The Good Practices on the Farm Program and Good Practices for Sustainability Program can be further strengthened regarding environmental management, which is crucial for the dairy sector worldwide [20].

While these programs are generally more robust and complete, they may need specific simplifications and adjustments in their scope and implementation to optimize their application, particularly for farms with average to high milk productivity.

Consequently, enhanced specialization among milk farmers and improved technical assistance are necessary to implement these BMP programs successfully. This aligns with Riedl and Maia [21], who state that the key indicator of regional development is the level of installed knowledge. It also supports the view of the OIE [22], which indicated that food safety and quality are best assured through an integrated, multidisciplinary approach encompassing the entire food chain and requiring specialized professionals to carry out risk-based recommendations.

The Quality Milk Production, Educampo, and Full Bucket programs must undergo essential improvements across all guide categories to ensure farms' viability from economic, social, and environmental perspectives [5,10]. Additionally, BMP programs enhance the image of the primary production sector and are critical for the management and sustainability of dairy farms. The Quality Milk Production Program is designed to ensure hygienic milking practices. However, milk handling should also be improved after milking to guarantee product quality until it reaches the dairy industry. The Educampo and Full Bucket programs, which are similar, display considerable completeness and robustness in socio-economic management, which is in line with the recommendations from Cervo *et al* [18]. Although less comprehensive than the Safe Food, Good Practices for Sustainability, Good Practices on the Farm, Quality Milk Production, Educampo, and Full Bucket programs, these initiatives can be an initial step in implementing best management practices in small—to medium-scale dairy operations [23].

## 5. Conclusion

All of Brazil's top management practices programs need adjustments to fully meet the recommendations set by the FAO & IDF, indicating a need for adjustments. However, these programs can be utilized together in a complementary way to enhance the sustainability of the dairy supply chain. The Safe Food, the Good Practices for Sustainability, and the Good Practices on the Farm programs are more comprehensive and could benefit from improvements in specific categories.

### Conflicts of interest statement

The authors declare no conflict of interest.

### Data availability statement

The data will be provided upon request.

### Author contributions

Conceptualization: H. B. A. Costa, R. M. Dantas and C. McManus. Data curation: H. B. A. Costa, M. B. Alvarenga and C. McManus. Formal analysis: C. McManus. Investigation: H. B. A. Costa, R. M. Dantas, M. B. Alvarenga and C. McManus. Metodology: H. B. A. Costa, R. M. Dantas, M. B. Alvarenga and C. McManus. Project administration: H. B. A. Costa. Supervision: C. McManus. Writing (original draft): H. B. A. Costa. Writing (review and editing): V. Peripolli, C. B. G. S. Tanure, L. Seixas, V. S. Junqueira and C. McManus.

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