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“On-farm” Production of Bioinputs in Brazil: Solution for Greater Agricultural Productivity or Imminent Risk to Public Health?

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HIGHLIGHTS

- Brazilian farmers are producing bioinputs “on-farm”.
- Most “on-farm” products contain contaminants.
- Poorly handled “on-farm” bioproducts pose a risk to human, animal, and environmental health.
- Bills seek to approve “on-farm” manufacturing.

Abstract: Even though population growth has slowed somewhat in recent years, the significant increase in human longevity poses a major challenge to food availability. For this, it is necessary to increase cultivated areas, which in many countries would mean using preservation areas or improving the productivity of areas already used for agriculture. To increase productivity without increasing environmental damage, many in the agricultural sector are adopting biological inputs as an alternative to chemical products. The production of a commercial bioinput, from its development to its approval for commercialization, includes numerous safety and effectiveness tests, which requires significant investment and time. Aiming to reduce the production costs of bioproducts, Brazilian rural producers are manufacturing their bioinputs “at home", i.e., the “on-farm” production. However, in several analyses of these bioinputs, contaminating microorganisms were identified, such as pathogenic bacteria, which, when increased in the cultures of “on-farm” products, can become a risk to human, animal, and environmental health. Although there is a legislative debate on this subject in Brazil, with the possibility of government inspection of production, there is still much to be clarified on this issue. Thus, this review article aims to alert the scientific community and government officials about the risks of this production practice, which could seem to be a solution for reducing costs in agriculture. However, without proper care, it can cause more significant problems, such as human, animal, and environmental contamination by handling pathogens not identified by the producer.

Keywords: bioinputs; *on-farm*; agriculture; sustainability; pathogenic microorganisms.

INTRODUCTION

Humanity reached the number of 8 billion people in 2022. Although this number represents a historic milestone, research shows that population growth is slowing down, with women having an average of 2.1 childbirths throughout their lives. Even so, the highest population growth rates are found in underdeveloped countries, raising concerns about sustainable development, including eradicating hunger and malnutrition [1]. The increase in life expectancy of the world population, which in 2018 had a higher number of older people (65 years or older) compared to the number of children under five years of age, presents itself as a new challenge in the search for sustainable development, including food security, which is already affected by soil degradation and climate change causing droughts and floods [2] and compromised agricultural production.

Focusing on food security and sustainability, Miranda [3] summarized data from the Global Food Security-Support Analysis Data project at 30 Meters (GFSAD30) from the National Aeronautics and Space Administration (NASA) and the United States Geological Survey United States (USGS) on the mapping of arable areas on the planet, in particular, data referring to Brazil. The research released in 2017 showed that Brazil uses only 7.6% (63,994,479 hectares) of its territorial extension for growing food, while 563,736,030 hectares belong to environmental preservation areas.

In this way, the urge to produce food to feed the global population, combined with the desire to limit the use of cultivable areas and to avoid the degradation of the environment, leads to the search for new solutions to increase the yield of food production in areas already used, thus demanding the development of new technologies and approaches to agroindustry. In this scenario, bioproducts are an alternative and show advantages over conventional inputs, such as contributing to the global economy, food security, and mitigating health and environmental damage. Bioproducts encompass biofertilizers, biostimulants, inoculants, and biopesticides with high and improved efficiency to improve production yield [4].

In the context of establishing a more productive and sustainable agriculture, we wrote this integrative review that seeks to provide scientifically based updates on the adoption of the practice of “on-farm” bioproduct production, its advances and limitations, as well as instructions from regulatory bodies, providing the reader with a critical view of the need for more sustainable, inclusive, and above all safe and high-quality food production.

Bioinput Market

According to IHS Markit, biopesticides contributed 8% to the global pesticides market in 2020, representing US$ 5.2 billion, with a growth projection of 16.4% and a movement of US$ 11.1 billion in 2025. The USA and Europe lead the biological control market, responsible for 60% of global production. In Brazil, the development of this sector is in substantial expansion, highlighting the agents of biocontrol, such as bioinsecticides and biofungicides [4]. Used in small, medium, and large farms, the biopesticides market in the country is growing considerably, increasing their use by 5.3% compared to usual pesticides [5].

A successful example was the development of an inoculant composed of two species of *Bacillus*, capable of solubilizing phosphates from the soil and making it available to the plant, reducing the use of chemical fertilizers and generating savings for the farmer, who by using the inoculant spends approximately US$ 60 (292.00 Brazilian reais) per hectare. In comparison, chemical fertilizer costs around US$ 500 (2,435.00 Brazilian reais) per hectare of corn cultivation [6]. In addition to the financial advantages, the planet benefits from implementing bioproducts in crops by reducing carbon dioxide (CO_2) emissions to the atmosphere. In Brazil, the use of products containing bacteria capable of carrying out biological nitrogen fixation (BNF) in soybean cultivation led to an estimated reduction of 236 million tons of CO_2 released into the environment [7], demonstrating the importance of these products for agricultural production becoming more sustainable.

Commercial and "on-farm" bioinputs

Due to the popularization and cost of commercial bioproducts, "on-farm" production has emerged in Brazil in the last twelve years to further reduce production costs. The term "on-farm" is used to characterize bioproducts manufactured by farmers on their farms [8], ensuring easier access to bioinputs in remote locations [9]. These products are generated by the multiplication of microbial strains, which reduces costs for producers by removing the need for transportation and storage [8, 10], thus reaching a savings of 58.6% in soybean production costs, as observed by Cruvinel and coauthors [11]. In addition to the savings generated, farmers see "homemade" production as a way to streamline the process, and take initiative because some do not want to wait for reliable scientific results, which are seen as time-consuming and bureaucratic [12].

However, the problem in carrying out this microbial multiplication on rural properties lies in the lack of adequate technical procedures and the absence of formulation and knowledge of the composition and quality observed in the industry, which guarantee the viability of the microorganism of origin and the sanitation criteria required by inspection authorities [8,13,14,15]. The low concentration of microorganisms due to inadequate production conditions is a critical concern, as it reduces product effectiveness [10].

Another factor driving "on-farm" production is the inclusion of biological products, such as biostimulants, in the portfolios of large chemical corporations. This action creates uncertainty for small producers. They fear these companies may control the market and reduce access to affordable biological products, similar to the scenario with chemical products [16].

Teckio and coauthors [17] calculated the costs for a producer to make a *Bacillus thurigiensis*-based bioinsecticide "on-farm" in a suitable facility. They then compared them to the cost of a chemical insecticide (methyl carbamate oxime). The study estimated an initial investment of about 4,000,000.00 Brazilian reais for infrastructure and materials to build a biofactory. Annual fixed costs would be about 693,000.00 Brazilian reais, with variable costs at around 270,000.00 Brazilian reais. This totals approximately US$ 716,000. Although the initial cost is high, the producer could gain 46.37% compared to investing in a chemical insecticide. This substitution offers advantages, but further studies are needed to compare costs using other microorganisms. We also emphasize the importance of comparing costs with commercial biological products.

Although the production and use of biological "on-farm" products are increasing in Brazil, a series of limitations need to be overcome, such as the traceability of the original inoculum to be multiplied (manufactured by specialized companies, supplied by renowned research institutions or even multiplied from commercialized products), the latter not being recommended due to the presence of stabilizers that can affect the fermentation process [5]. In addition, consideration must be given to microbial selection and specificity, ability to compete and survive with native soil microbiota, climatic conditions, availability of skilled labor, authorization by regulatory bodies, and acceptance by farmers [18].

Regularization, law projects and risks involving the "on farm" production

In opposition to the "on-farm" production, companies must go through the Brazilian government regulation process to participate in this market. The same situation is observed for North American legislation. There are, in Brazil, law projects to facilitate the production and consumption of bioinputs "on-farm", aiming to classify the activity as low risk and exempt the registration of the product once the microorganism used as a base was already registered and used as an active ingredient in other bioproducts [4].

In 2020, the Ministry of Agriculture, Livestock and Food Supply (MAPA) launched the National Bioinputs Program to encourage the practice and propose federal public initiatives to develop the use of bioproducts in the country, promote sustainable agriculture, and regulate the production of these products, encompassing production in the field [19].

To regulate the practice of "on-farm" production, Brazil passed Law No. 15,070 in December 2024. This law establishes a new regulatory framework for the production, use, and sale of bioinputs in the country. It waives the registration requirement for bioinputs produced for own consumption on rural properties, which, in this case, cannot be sold. These facilities must have the necessary infrastructure and equipment for quality control and adhere to good practice guidelines. According to the law, production units will have a simplified registration process and may be exempt from registration with a federal agricultural protection agency. The supervision and inspection of products and establishments are the responsibility of the federal, state, or district agricultural protection agency. In the case of "on-farm" production, there is no need for mandatory technical analysis by the National Health Surveillance Agency (ANVISA) or the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA) [20]. The Ministry of Agriculture, Livestock, and Food Supply (MAPA) is responsible for defining requirements for the registration, inspection, production, use, packaging, and labeling of bioinputs (Ordinance SDA/MAPA No. 1,270, dated April 25, 2025). To carry out these functions, working groups will be established, comprising members of MAPA itself, the Brazilian

Agricultural Research Corporation (EMBRAPA), and representatives from bioinput and agribusiness entities, to ensure participatory and transparent regulation [21].

Examining other Latin American countries, we observe that Argentina approved in April 2025 Resolution RESOL-2025-214-APN-PRES of the National Agrifood Health and Quality Service (SENASA), which establishes the regulatory framework for the registration, import, export, marketing, and inspection of fertilizers, bioinputs, and their derivatives. Registration is mandatory for individuals and legal entities involved in production, fractionation, import, or export. The document defines quality parameters, contamination limits, labeling criteria, and acceptable tolerances for different categories (chemical fertilizers, biological fertilizers, stimulants, among others), and registrations can be suspended if phytosanitary or environmental risks are detected [22]. The resolution does not mention the production of "on-farm" bioinputs.

Similarly, in Colombia, the Colombian Agricultural Institute (ICA) resolution 68370/2020 establishes rules for the registration of producers, bottlers, importers, and bioinputs for agricultural use in the country. It determines that any individual or legal entity involved in the production or sale of bioinputs must register with the institute. The resolution does not mention "on-farm" production, but there are initiatives to achieve this, such as the Peasant Promotion School, launched by the Ministry of Agriculture and Rural Development in partnership with the Rural Development Agency (ADR), with the aim of training family and community farmers, focusing on the production and use of bioinputs, such as the multiplication of natural microorganisms, among others [23].

In North America, regulatory oversight of agricultural inputs is multilayered. For example, the Environmental Protection Agency (EPA) in the United States regulates biological pesticides, requiring registration, efficacy testing, safety testing, and labeling for both commercial and experimental use. Meanwhile, the United States Department of Agriculture (USDA) oversees biofertilizers in organic agriculture through the National Organic Program (NOP) [24,25]. Similarly, in Mexico, regulation is conducted by the Mexican National Research Institute for Forestry, Agriculture, and Livestock (INIFAP), with additional support for domestic production provided at state and federal levels through the Production for Well-being program [9].

Examining standardizations beyond Latin America, in the European Union (EU), a new regulation on fertilizers ((EU) 2019/1009) establishes the necessary actions for the release of biofertilizers, such as assessing human and environmental safety, good manufacturing practices, nutrient efficiency, whether based on biofertilizer availability or plant efficiency in utilizing it, and product labeling, which must include the name of the microorganism, its function, and instructions for use [25]. China is one of the most highly regulated countries in the use of fertilizers, whose quality is defined according to the number of viable cells, pH, water-to-carbon ratio, shelf life, presentation, and contaminants [25]. Biopesticides are classified into three categories: microbial, biochemical, and botanical pesticides. The Chinese regulatory body is the Ministry of Agriculture and Rural Affairs (MARA). Our searches found no information on "on-farm" production [26,27]. Information on the regulations of the mentioned countries is summarized in Table 1.

However, to produce bioproducts on an industrial scale in Brazil, registration is simplified only for biodefensives. This simplification may happen once similar products are registered in the regulatory body. This rule is valid if the defensive product contains the same composition and the same microbial isolate as the registered standard product, including approval against environmental and human health risks and, in addition, proof of its agronomic efficiency [28].

Table1. Regulation of "on-farm" production in different countries

Country	"On-Farm" Production Allowed	Regulatory Authority	References
Brazil	Yes	MAPA	[20,21]
Argentina	No	SENASA	[22]
Colombia	No*	ICA	[23]
Mexico	No*	INIFAP	[9]
United States	No	EPA, USDA (NOP)	[25]
European Union	No	European Commission	[25]
China	No	MARA	[25,26,27]

*Movement for "on-farm" use underway

There are private companies that provide specialized support services for farmers to produce their own bioinputs, providing infrastructure and training by qualified professionals [12]. The training provided by microbiologists certainly reduces the risk of contamination in products manufactured by farmers, however, it is necessary to understand that the identification of a microorganism is not a simple task, and nowadays, these identifications require molecular biology tools, such as housekeeping-gene sequencing [29]. This technology is difficult to implement in a rural property, mainly due to the high cost of equipment and reagents.

Therefore, the "on-farm" practice represents a significant challenge for the Brazilian authorities, who must direct their actions towards the potential problems generated by this practice, whether biological risks to human health and the environment (interaction with the soil microbiome and positive or negative impact on it), transfer of genetic material between pathogenic and non-pathogenic microorganisms, and also the possibility of biopiracy and misuse of property rights. In addition, there will be a demand to disseminate scientific knowledge (generated from investment in research that seeks to elucidate the influence of these bioinputs on the ecosystem to which they are inserted) amongst professionals from different areas and producers of all socioeconomic levels to mitigate future problems [30].

These problems have already been described in "on-farm" studies, such as the on biopesticide containing *Bacillus thuringiensis*. This is a product regulated by Brazilian legislation and has a specific application. However, the "on-farm," version has been reproduced without due care. Ten samples from this product were collected from different rural producers in the state of Goiás, Brazil, and evaluated for the presence of contaminants, and an analysis of cultivation and identification by 16S rDNA showed that only 2.5% of the microorganisms present in the bioinsecticide belonged to the original strain (*B. thuringiensis*). The other 97.5% were identified mainly as pathogenic bacteria of the *Enterococcus, Acinetobacter*, and *Morganella* genera, among others, with unknown effects on mammals. These analyses reflect the lack of asepsis and quality control during manufacturing. These results classify the “on-farm” biopesticide produced by these farms as not recommended for crop use because it risks human and animal health [13].

In a similar evaluation, Valicente and coauthors [31] collected samples of a biopesticide based on *B. thuringiensis*, manufactured in three rural properties in the Brazilian state of Mato Grosso. After plating the respective samples, they obtained 50 bacterial colonies, of which only three were identified as *B. thurigiensis* by the 16S rDNA gene amplification method. Among the other isolates, other species of *Bacillus*, *Microbacterium* (genus containing species that are multi-resistant to antibiotics), *Enterococcus gallinarum*, and *E. casseliflavus* (species related to endocarditis) were identified, in addition to the environmental bacterial genera *Brevibacillus*, *Paenibacillus*, *Pseudoxanthomonas*, and *Methylobacterium*. The authors associated the high contamination rate of the samples with the lack of standardization of the production process, sterilization, and asepsis, causing risk to animals and humans and, therefore, being unsuitable for use as biopesticides. In addition, the research points out that most “on-farm” production of biopesticides in Brazil is stored in water tanks or metal tanks with openings that favor contamination.

Inadequate facilities and lack of aseptic practices were also observed by Kovalski and coauthors [32]. The study evaluated samples of “on-farm” biological fermented products in four biofactories located on rural properties in the Curitibanos region of Santa Catarina, Brazil. To manufacture the bioinput, the rural producers used bacterial (*Bacillus subtilis, B. thuringiensis*) and fungal (*Trichoderma harzianum*) inocula from commercial products that were expired or had opened packaging. The fermentation process was carried out in water tanks or in an adapted milk cooler, and the environments lacked hygiene controls. The researchers observed the reuse of agrochemical containers for storing fermented products on one property, and on others, the presence of livestock (chickens, geese, and sheep) near the production site. When analyzing the purity of the fermented products “on-farm”, the researchers found contamination in all samples, and only one contained the organism of interest (*B. thuringiensis*). The color and pH of the fermented products also differed from those of commercial products, and one sample contained flies. Although the contaminating microorganisms were not identified, it was concluded that none of the fermented products were suitable for agricultural use and that they posed risks to human and environmental health.

In opposition to this, when “on-farm” production of *Bacillus thurigiensis*-based insecticide was carried out safely (with adequate facilities, an automated and sanitized stainless steel biofactory, treated water, careful handling, and a reliable and pure inoculum), the product was effective against *Spodoptera frugiperda* larvae and free from contaminants. The number of *Staphylococcus* and thermotolerant coliforms was considered within permitted concentrations ($\leq 10^3$ CFU/g or CFU/mL). Sequencing of the *rpoB* gene identified two other bacterial species in the sample, *Enterobacter hormaechei* and *Ralstonia pickettii*, which are classified as non-contaminating by Brazilian regulatory agencies [33].

Despite these regulatory classifications, it is essential to acknowledge that these pathogens are considered non-contaminants because they are characterized as low-virulence and primarily affect immunocompromised patients and/or those in hospital settings. However, recent genome evaluations of these species have demonstrated that *E. hormaechei*, isolated from a lymphoma patient, exhibits multiple drug resistance, with 12 genes identified. *R. picketti*, meanwhile, possesses elements related to antimicrobial resistance and virulence factors. In addition to its high adaptability to extreme environmental conditions, it can cause numerous severe infections, including patient deaths. These characteristics of *R. picketti* have been observed in drinking water samples [34,35]. Given the above, the need for constant and precise monitoring of bioinput processing, as well as regular updates from regulatory agencies, becomes clear and urgent.

In another relevant context, large-scale production of different *Bacillus* species (*B. thuringiensis*, *B. subtilis*, *B. methylotrophicus*, *B. pumilus*, and *B. licheniformis*) isolated from soil samples from the farm itself showed adequate spore concentration and a contaminant-free fermented product when applying quality and efficacy control methodologies and practices, in addition to an adequate physical structure [12,36], demonstrating that rigor in the manufacturing process can make a homemade bioinput efficient and safe from isolation to application. Contrary to what has been explained, when evaluating the cultivable microbial diversity of the soil and using it in an “on-farm” formulation without commercial purposes, Bomfim and coauthors [37] identified a large number of species of bacteria, fungi, yeasts, and actinomycetes with biotechnological potential, such as *Bacillus*, *Streptomyces,* and *Trichoderma*. However, among the recognized genera, several contained pathogenic species, such as *Escherichia*, *Klebsiella*, *Enterococcus*, *Staphylococcus*, *Corynebacterium, Pseudomonas*, *Stenotrophomonas*, *Candida*, *Aspergillus*, *Cladosporium*, and *Mucor*. Although the authors did not identify the source of contamination, the conditions of sterilization, asepsis, and handling during formulation were not specified. These results demonstrate the importance of species-level identification to validate the use of these strains as bioinputs. The use of molecular biology tools can meet this need, but a partnership between the producer and an institution that supports this technology would be required.

When analyzing samples of inoculants based on *Bradyrhizobium* spp. and *Azospirillum brasilense* produced “on-farm” in different regions of Brazil, Bocatti and coauthors [15] identified 25 bacterial genera colonizing these inoculants, of which 44% were pathogenic genera or with potential for pathogenicity in humans, and many presented resistances to antibiotics. Among the pathogenic genera, representatives of *Enterobacter*, *Citrobacter*, *Acinetobacter*, *Enterococcus*, *Atlantibacter*, *Klebsiella*, *Staphylococcus*, *Burkholderia*, *Stenotrophomonas maltophilia*, and *Escherichia coli* were identified. Only one sample showed the desired microorganism (*A. brasilense*), proving that the culture method used is ineffective in multiplying commercial inoculant strains. The high rate of contamination in inoculants produced “on-farm” was attributed to the incorrect use of culture media, inadequate cultivation time, acidic pH, and competition for nutrients since the generation time of pathogenic microorganisms is shorter when compared to *A*. *brasilense* and *Bradhyrhizobium* spp. The undesired microorganisms then take advantage of the use of nutrients being able to colonize the culture media faster. In this context, producing inoculants "on-farm" was considered a practice with potential risk to human health.

Total coliforms were identified in 84% of the samples of "on-farm" inoculants analyzed in the region of Vale do São Francisco (Brazil), and of these, 75% were thermotolerant coliforms. The presence of *Salmonella* spp. was also verified when culturing the samples in *Salmonella-Shigella* (SS) medium in 75% of the samples analyzed. The authors found some contamination in all products analyzed, representing twelve farms, where inadequate installation conditions, hygiene, quality control, and culture media were identified [14].

Regarding the production “on-farm” of bioproducts with fungi as bioactive compounds, some cases of allergies caused by *Trichoderma, Metarhizium anisopliae*, and *Beauveria bassiana* have been reported in immunocompromised patients and workers from the area [38]. Other fungi can easily contaminate the "on-farm" production without adequate technical supervision with similar morphology. Such opportunistic fungi can harm human health by producing toxins [39]. However, when comparing the use of “on-farm” bioproducts (*B. subtilis*, *B. thurigiensis*, *Trichoderma* spp., *M*. *anisopliae*, *B*. *bassiana*, and *Pochonia chlamydosporia*) with conventional chemical products (nematicides, fungicides, and insecticides) against diseases and pests that affect soybeans (*Glycine max*), Cruvinel and coauthors [11] obtained higher grain productivity when “on-farm” products were used. Nonetheless, the production of biological inputs was carried out in a specific structure for this purpose, with separate rooms for the different stages of inoculation, humidity control, temperature, light, and laboratory equipment necessary to guarantee the quality of the product. To address the challenge of “on-farm” fungal isolation, researchers developed a methodology using baits to promote fungal growth (*Trichoderma*) from sugarcane stalks planted in rural areas and subsequently incubated in humid chambers at room temperature. The green fungi were reinoculated onto another stalk using an autoclaved toothpick, and after growth, they were identified and purified in a university laboratory. The technique's success required appropriate equipment (autoclave, laminar flow, microscope) and culture media, as well as the support of specialized personnel [40]. The method included simple isolation procedures, which facilitated implementation by farmers, but did not eliminate necessary precautions such as sterilization and identification. Partnerships with research institutions or universities can be an attractive alternative for producers who prefer not to invest in their own infrastructure.

Expanding on the types of bioinputs tested, when producing a heterogeneous biostimulant containing a bacterial consortium (*Herbaspirillum seropedicae*, *Bacillus safensis*, *B. pumilus*, and *Gluconacetobacter diazotrophicus*) and humic substances extracted from vermicompost for application in passion fruit crops, growth-promoting and biodefensive action was observed, reducing symptoms caused by diseases and pests. The product was fermented in a polypropylene reactor with temperature control and a forced air inlet. The culture medium used contained commercial fishmeal and molasses, and the water used was previously boiled. Cell counts of the fermented product were performed in a university laboratory [16], but contaminant analysis was not performed, raising doubts about the product's quality.

Despite some advantages that “on-farm” production might have, some critical aspects must be considered. In industrial production, these products are originated from the multiplication of a pure strain, in laboratories, with a formulation that preserves the viability of the microorganism from the production until the application, respecting the product's shelf life [8,41]. The product must also be standardized, reproducible, and meet quality criteria, such as providing the minimum number of viable cells and storage stability over time, in addition to ensuring the safety of people and the environment exposed to it, and maintaining the concentration of microorganism contaminants within acceptable limits [42].

The complexity of maintaining quality control in the manufacture of biological products must be mentioned, having as the main criterion the obtaining of a pure inoculum whose identity of the microorganism is reliable, preferably obtained by molecular identification techniques, capable of differentiating species within the same genus. Each microorganism's natural characteristics and nutritional requirements must also be considered, as these singularities can directly interfere with the production process [25]. Another essential criterion for bioproducts is related to safety, with restrictions of the use of pathogenic risk groups of microorganisms, confined to isolation from the risk #2 group or risk #1 [38]. Some of these criteria can be neglected in “homemade” production.

This literature review leads us to reflect on the importance of more sustainable food production and equal opportunities for producers with fewer financial resources. Indeed, when “on-farm” bioinputs are produced in an appropriate manner, they can bring significant benefits to both the community and the environment involved. However, as already highlighted, there are weaknesses that still need to be better discussed in the areas of health, education, and policy. For example, will there be subsidies for small producers to receive quality training? Or for them to use biotechnological tools to ensure a contaminant-free product? Do regulatory agencies have sufficient inspectors to meet this demand? In the scientific field, there are still few studies reporting on the quality of “on-farm” products. These analyses need to be expanded to inform decision-making regarding inspections and future public policies. Engaging scientists with these farmers can contribute to a deeper understanding of concepts related to asepsis and good manufacturing practices.

Antimicrobial resistance

Another relevant element that has been ignored in the "on-farm" production is the potential risk of disseminating antibiotic-resistant microorganisms in cultivated foods and the environment. Antimicrobial resistance (AMR) is a growing and worrying factor that affects the entire world and can be considered a "global epidemic" due to the ineffectiveness of antibiotics on the market against many microorganisms, especially against pathogenic bacteria [43], or even classified as a "universal crisis", affecting not only humanity but also animals and the environment [44].

The severity of AMR is evident in death rates. In 2019, resistant bacteria were responsible for approximately 1.27 million deaths. This number is expected to approach 10 million by 2050. The most lethal pathogenic bacteria include *Escherichia coli*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Streptococcus pneumoniae*, and *Pseudomonas aeruginosa* [45,46]. Analyses of different “on-farm” products in this review identified one or more of these microorganisms [13,15,37].

The conscious use of antibiotic administration on farms, especially in animal production, is gaining support from government leaders to minimize the risks of AMR in the so-called "OneHealth" approach (which encompasses human, animal, and environmental health) [47].

Resistant bacteria have antimicrobial resistance genes (ARGs), which can be disseminated through different soil, water, air, and sediment routes. In agricultural practice, propagation occurs mainly through irrigation via wastewater. In bacteria, the acquisition of AMR is a natural evolutionary process, and the propagation of ARGs can occur through environmental selection (indiscriminate use of antibiotics that are deposited in the environment, heavy metals, biocides, herbicides, pesticides, pharmaceuticals, nanomaterials, and agents' stressors) or by genetic mechanisms (mutations, mobile genetic elements like transposons, plasmids, prophages, integrons, and/or cassette genes). Mobile genetic elements favor gene recombination of ARGs, which can be transmitted even to different species through horizontal gene transfer (HGT), which includes transduction, conjugation, and transformation mechanisms [43,48,49]. To better understand these mechanisms, read the review by Partridge and coauthors [50].

Antibiotic residues from different sources are deposited in the environment, and even if they are found in low proportions, they are considered persistent environmental contaminants, which promote the generation of selective pressure in resistance genes and their transfer via HGT. Among other possibilities, resistance genes can be transmitted to humans through food, being found in considerable concentrations in grains and leaves of vegetables, affecting the gut microbiota and feeding back the cycle of resistance [43,49].

An example of the severity of the transfer of ARGs through genetic mechanisms is the multi-resistant bacteria SKAPE (*Staphylococcus aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, *Enterococcus faecium*, and *Enterobacter* spp.), responsible for severe infections with a high mortality rate due to the loss of effectiveness in treatment by antibacterials already available on the market, being considered a threat to the life of all humanity [51]. Among the genera that comprise the SKAPE pathogens, five were identified as contaminants in "on-farm" products analyzed by Bocatti and coauthors [15]. Additionally, three other studies identified one or more SKAPE pathogens in their products [13,33,37], further demonstrating the prevalence of these pathogenic microorganisms.

There is a program of prevention and control for resistant bacteria in Brazil- the National Action Plan for the Prevention and Control of Antimicrobial Resistance in the Agriculture Approach (*Plano de Ação Nacional de Prevenção e Controle da Resistência aos Antimicrobianos no Âmbito da Agropecuária* (PAN-BR AGRO), that is in line with the quadripartitis alliance signed between the World Health Organization (WHO), World Organization for Animal Health (WOAH), Food and Agriculture Organization of the United Nations (FAO) and United Nations Environment Program (UNEP) [52]. This program, PAN-BR AGRO, encompasses actions proposed by the Brazilian Ministry of Agriculture, Livestock, and Food Supply - *Ministério da Agricultura Pecuária e Abastecimento* (MAPA) - against resistance in farming production. However, the actions of this ministry are focused on the control of antimicrobials in livestock, either by reducing the use of these drugs in the animal life cycle or prophylactic action against infectious diseases in livestock production [53], without clarifying what actions will be carried out in plant production.

MAPA's performance in controlling resistance to antimicrobials in Brazilian livestock production is very important to achieve the objectives of the national and global plans. Nonetheless, with the popularization of “on-farm” bioproducts, the action of this ministry in monitoring the presence of microorganisms that contain ARGs in “home- produced” bioinputs is urgent and necessary.

In this way, biological products produced “on-farm” that contain contaminating bacteria resistant to antibiotics can become another source of transmission of ARGs by allowing these organisms to come into contact with non-resistant strains, transforming these bioinputs into potential agents against human health by introducing pathogenic microorganisms and also by increasing the spread of ARGs, thus contributing to the ineffectiveness of the treatment of bacterial infectious diseases.

Based on Brazilian studies that analyzed “on-farm” products, a discussion about ANVISA's role as a regulatory body for home biofactories is extremely urgent and should be reconsidered by Brazilian political representatives, as this is a public health issue not only in Brazil but globally.

Faced with bad practices in the “on-farm” production process, activities to raise farmers' awareness about the risk of using "homemade" bioinputs have been organized through social marketing. Companies and public agricultural research institutions aim to expose the real cost-benefit of this practice, emphasizing that the structure to maintain optimal quality control requires a high financial investment [54].

CONCLUSION

According to the scientific data presented in this article, facilitating the use of “on-farm” bioinputs without strict quality control and surveillance can lead to problems for the environment, the consumer, and the producer, affecting sustainable development and human, animal, and plant health. The verification of the biosafety of microorganisms before the registration and propagation of any bioproduct, whether “on-farm” or not, is of fundamental importance, taking into account, among others, the risks of pathogenicity and resistance to antimicrobials.

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