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What is the importance of good agricultural practices to prevent mycotoxin contamination in cheese processing? Insights from Brazilian dairy farmers

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Abstract

This study evaluated dairy producers' perceptions of the importance of good agricultural practices (GAP) for preventing aflatoxin contamination during cheese production in the Sertão do Araripe region, Pernambuco, Brazil. Twenty-six milk and cheese producers were interviewed in person between March and April 2022 using a structured questionnaire containing 53 statements scored on a five-point Likert scale. Hierarchical cluster analysis identified two respondent groups, and factor analysis was used to assess response structure and internal consistency. Although the producers generally recognized the value of GAP for obtaining safer food, important knowledge gaps were observed regarding aflatoxins, their fungal origin, their transfer from feed to milk and cheese, and the preventive role of feed storage and hygienic practices. Misconceptions were also found regarding the effect of heat treatment on aflatoxins and the relationship between contaminated feed and product quality. The results indicated that general awareness of farm hygiene and animal health measures was higher than specific knowledge about aflatoxin prevention. These findings suggested that targeted educational programs and extension actions are needed to strengthen producer knowledge and support the implementation of preventive practices across the dairy chain.

Introduction

In recent years, consumers have shown increasing concern about the health, safety, and quality of food. Nevertheless, milk and dairy products remain vulnerable to physical, chemical, and microbiological contamination because the raw material is highly perishable (Raza and Kim 2018; Claeys et al. 2020). Among chemical hazards, aflatoxins deserve particular attention because of their relevance to public health and the dairy economy (Kumar et al. 2017; Klingelhöfer et al. 2018).

Aflatoxins are toxic secondary metabolites mainly produced by Aspergillus flavus and Aspergillus parasiticus. These fungi can colonize grains and other feed ingredients under favorable conditions, especially high temperature, moisture, and inadequate storage (Kumar et al. 2017; Mahato et al. 2019). Corn, sorghum, and soybeans, which are commonly used in dairy cattle feeding, are particularly susceptible during crop production, feed processing, and storage (Atanda et al. 2013; Feddern et al. 2013).

After ingestion of aflatoxin B1 (AFB1)-contaminated feed, dairy animals can biotransform part of the toxin into aflatoxin M1 (AFM1), which is excreted in milk (Jiang et al. 2021). Because AFM1 can partition into cheese during manufacture, consumers of milk and dairy products may be exposed to this contaminant (Campagnollo et al. 2016; Khaneghah et al. 2021; Mohammadi et al. 2022). This issue is relevant because aflatoxins are associated with carcinogenic, mutagenic, and teratogenic effects (Marchese et al. 2018; Claeys et al. 2020; Ostry et al. 2017). In Pernambuco State, AFM1 has already been reported in artisanal and manufactured cheeses, reinforcing the regional relevance of this topic (Silva et al. 2023).

Good agricultural practices (GAP) include principles, standards, and management actions that improve the safety and quality of agricultural products while also supporting environmental, economic, and social sustainability (FAO 2016). In dairy systems, GAP can contribute to safer feed production, better animal health management, improved hygiene, and reduced contamination risks throughout milk and cheese production (FAO and IDF 2011; Dereti et al. 2019; Xu et al. 2022).

Because producers play a central role in implementing preventive measures, their perceptions and knowledge are important for the effectiveness of aflatoxin control strategies (Udomkun et al. 2018; Yunus et al. 2022). In this context, the present study evaluated the perceptions of dairy producers from the Brazilian Northeast regarding the importance of GAP for preventing aflatoxin contamination during cheese production.

Materials and methods

This study used a non-probability convenience sample because of its practical applicability in field conditions (Stratton 2021). All participants (n = 26) were milk and cheese producers living in the Sertão do Araripe region of Pernambuco State, Brazil. Producers were selected according to their willingness and availability to participate. All participants confirmed that they were at least 18 years old and were informed that their data would be collected for scientific purposes. Face-to-face interviews were conducted on dairy farms between March and April 2022.

The research protocol was approved by the Research Ethics Committee involving Human Subjects of the Federal Rural University of Pernambuco (CAAE: 5354.204/2022). All participants signed an informed consent form before inclusion in the study.

The questionnaire contained two sections. The first section collected sociodemographic information, including gender, age, educational level, and time working in dairy production. The second section assessed the producers' perceptions of the importance of GAP for preventing aflatoxins during cheese production. This section comprised six thematic parts: knowledge about GAP; knowledge about aflatoxins; sanitary management and hygiene; feed management, feed storage, and water quality; milking and post-milking management; and workers' health, habits, and personal hygiene. Responses were recorded on a five-point bipolar Likert scale (1 = completely disagree, 2 = partially disagree, 3 = neither agree nor disagree, 4 = partially agree, 5 = completely agree).

All statistical analyses were performed using XLSTAT 2021.4 (Addinsoft, Paris, France). Questionnaire data were first evaluated by hierarchical cluster analysis (HCA) to identify groups with similar or dissimilar response patterns. Mean scores for the statements were then compared between groups using the independent t test. In addition, factor analysis (FA) was performed, and internal reliability was assessed using Cronbach's alpha. Factor scores were calculated from the corresponding means and standard deviations.

Results and discussion

Table 1 summarizes the sociodemographic characteristics of the respondents. Of the 26 interviewees, most were male (80.77%). Most producers were 36 to 55 years old (53.84%), followed by those aged 56 to more than 60 years (34.61%). Regarding educational level, incomplete primary education was the most frequent category (34.61%), whereas 23.07% had completed high school. Most participants (92.30%) had worked in dairy production for more than 10 years.

Table 1
Sociodemographic characteristics of the respondents

Characteristics	**n**	**%**
Gender		
Female	5	19.23
Male	21	80.77
Age range (years)		
18 a 35	4	15.38
36 a 55	14	53.84
56 a > 60	9	34.61
Education Level		
No Schooling	2	7.69
Incomplete primary Education	9	34.61
Complete Primary Education	3	11.53
Incomplete High School	1	3.84
Complete High School	6	23.07
Incomplete Higher Education	1	3.84
Complete Higher Education	2	7.69
Postgraduate	1	3.84
Years in dairy production		
< 5 years	1	3.84
5–10 years	1	3.84
> 10 years	24	92.30

The hierarchical cluster analysis separated the respondents into two groups with 13 producers each (Fig. 1). Group 1 was generally younger and reported higher milk and cheese production volumes than Group 2, suggesting that age and production profile may have influenced perceptions related to GAP and aflatoxin control.

When producers were asked to identify factors favoring aflatoxin occurrence and the impacts of aflatoxins on food production, most were unable to provide specific answers. Only a few participants cited cattle feeding, poor milking hygiene, or animal care. Reported impacts were limited to production losses, animal death, and increased costs. These findings indicated limited specific knowledge about aflatoxins among the respondents, in agreement with previous studies showing low awareness of aflatoxin contamination among livestock farmers (Ayo et al. 2018; Kuisa et al. 2017; Udomkun et al. 2018; Yunus et al. 2022).

Table 2 presents the mean scores, standard deviations, and p values for all questionnaire statements. The internal consistency of the questionnaire was considered good, with a Cronbach's alpha of 0.81, which indicates adequate reliability for this type of instrument (Bujang et al. 2018). In the section addressing knowledge about GAP, there were no significant differences between the two groups for the general statements, and most respondents agreed that GAP should be applied on farms and contributes to safer food. However, when asked whether GAP can reduce food losses caused by aflatoxins, both groups were largely undecided.

Table 2. Mean scores of responses to sentences about dairy farmers' perceptions related to how Good Agricultural Practices can prevent aflatoxins in cheese production[1]

Sentences	Group 1	Group 2	
	Mean (±SD)	Mean (±SD)	p-value
PART 1 - KNOWLEDGE ABOUT GOOD AGRICULTURAL PRACTICES			
1. Good agricultural practices must be applied in the pre and post-production processes on the farm	4.53±0.75	4.08±1	0.211
2. Implementing good agricultural practices produces safe food	4.69±0.72	4.31±0.82	0.235
3. Good agricultural practices reduce risks to the health of consumers and food handlers	4.53±1.15	4.23±0.80	0.454
4. The implementation of good agricultural practices reduces food losses caused by aflatoxins	3.08±1.14	3.54±1.22	0.347
PART 2 - KNOWLEDGE ABOUT AFLATOXINS			
5. Aflatoxins are produced by fungi	2.85±0.53	3.44 ±0.23	0.327
6. Aflatoxins are prejudicial to human and animal health	3.46±0.84	3.22±0.34	0.07
7. Food provided to animals must be free of aflatoxins	3.69±0.82	3.12±0.56	0.007*
8. Aflatoxin can be found in animal feed	3.31±1.07	3.12 ±0.45	0.327
9. Proper preparation and storage of feed prevents contamination by aflatoxins	3.38±0.92	3.54±0.56	0.162
10. To prevent contamination of feed by aflatoxins. temperature and humidity control must be carried out during storage	3.69±0.91	3.21 ±0.34	0.015*
11. Separating new feed from old and removing moldy feed prevents aflatoxins	3.54±0.84	3.45 ±0.45	0.037*
12. The consumption of aflatoxin-contaminated feed reduces milk production and quality	3.15±1.23	3.02±0.61	0.669

13. Aflatoxin passes from feed to milk and then to cheese	3.77±0.97	3.34 ±0.23	0.011*
14. Aflatoxin can contaminate cheese	3.69±0.91	3.56 ±0.77	0.015*
15. Heat treatment reduces the amount of aflatoxin in cheese	3.77±0.97	3.45 ±0.78	0.011*
16. Consumption of food contaminated by aflatoxins can lead to liver cancer	3.77±0.97	3.12 ±0.32	0.011*
PART 3 - SANITARY MANAGEMENT AND HYGIENE			
17. It is important to individually identify animals from birth to death	2.69±1.90	1.60±1.15	0.105
18. It is mandatory to vaccinate all animals periodically	5.12 ±0.45	5.54 ±0.56	1
19. It is necessary to carry out periodic examinations for brucellosis and tuberculosis	4.85±0.36	4.38±0.62	0.036*
20. When buying new animals. you must keep them separate for a period	3.77±1.67	2.62±1.5	0.087
21. The accumulation of feces and urine in the stables must be avoided. carrying out frequent cleaning of these places	412±1.41	2.77±1.48	0.048*
22. It is necessary to carry out pest control	3.69±1.43	1.69±0.91	0*
23. Rats. flies. cockroaches. birds. cats or other animals threaten the safety of milk and cheese	3.69±1.49	2±1.11	0.004*
24. All equipment and utensils used in milking and storing milk must be properly sanitized	4.92±0.27	4.84±0.36	0.558
25. After cleaning. utensils and equipment must be stored in a clean and dry place. protected from dust and insects	4.38±1.02	3.46±0.93	0.028*
PART 4 - FOOD MANAGEMENT. FOOD STORAGE AND WATER QUALITY			
26. Food and water provided to animals must be free of contaminants	4.77±0.58	4.61±0.62	0.536

27. Water sources must be of good quality and free from contamination	4.77±0.58	4.77±0.42	1
28. Wells and springs should be fenced off to keep out animals and kept clean around them	4.92±0.27	4.38±0.84	0.044*
29. The wells must be covered and have a small cement sidewalk with ditches around it	5.11±0.45	4.54±0.75	0.042*
30. Water tanks and cisterns must be covered. without cracks. infiltrations or leaks	4.85±0.53	4.54±0.75	0.256
31. Sanitation of reservoirs must be done frequently	4.92±0.27	3.77±1.25	0.005*
32. The ingredients used in the formulation of diets must be purchased from suppliers approved by the Ministry of Agriculture	3.85±1.56	3.69±0.72	0.759
33. The feed storage area must be clean. with adequate ventilation. free from pests	4.08±1.44	4.08±1.14	1
34. The feed must be stored in a dry and ventilated place	4.08±1.44	4.46±0.75	0.419
35. Feed bags can be placed directly on the floor	2.92±1.86	3.08±1.77	0.837
36. It is important to check the condition of the feed before giving it to the animals	4.31±1.32	4.23±1.48	0.894
PART 5 - MILKING AND POST-MILKING MANAGEMENT			
37. Milking practices that may cause injuries to animals must be avoided	4.69±0.72	5.12 ±0.45	0.153
38. The milker must wash his hands well before and after each milking	4.38±0.92	4.77±0.58	0.233
39. The milking location influences the quality of milk	4.77±0.58	3.92±1.54	0.088
40. Disinfection of the animal's udder is an important step before and after milking	4.38±0.84	2.23±1.62	0*

41. Milking equipment must be cleaned and disinfected after each milking	4.31±1.20	4.15±1.23	0.759
42. Milk obtained from sick or treated animals must be separated for proper disposal	4.15±1.56	4.69±1.07	0.334
43. No need to despise the first jets	3.38±1.82	3.54±1.69	0.832
44. Performing the black background mug test is an important procedure	4.31±1.14	1.00±0.12	<0.0001*
45. Milk cooling must be done immediately after milking	2.77±1.37	1.54±1.15	0.025*
PART 6 - WORKERS HEALTH. HABITS. AND PERSONAL HYGIENE			
46. Milkers cannot have wounds on their hands. arms. or forearms	4.08±1.69	4.62±0.74	0.321
47. The milker who presents with fever. diarrhea. tuberculosis. otitis. and pharyngitis should be removed from work	4.85±0.53	4.85±0.36	1
48. Workers must undergo examinations at least once a year	3.46±1.34	3.77±1.37	0.582
49. All employees who deal with animals must be vaccinated against zoonoses	3.15±1.87	4.85±0.53	0.006*
50. It is essential for the worker to perform personal hygiene. such as bathing daily. short. and clean nails. cut hair and trimmed beard in the case of men	4.62±0.74	3.77±1.12	0.039*
51. The use of rings. watches. ribbons. strings. which may fall into milk containers. is prohibited	3.77±1.62	4.15±1.17	0.512
52. Employees must wear clean uniforms. rubber boots and aprons	4.38±0.74	3.54±1.01	0.028*
53. During milking. employees should not smoke. eat. spit. blow their nose. wipe sweat with their hands. run their hands over the animal’s hair	4.69±0.61	3.62±1.08	0.006*

[1]Results were express as mean±(SD) based on 5 point *Likert* scale: 1=strongly disagree. 23= neither agree nor disagree, 5=strongly agree. *The calculated p-value is lower than the significance level alpha=0.05; therefore. the null hypothesis H0 must be rejected. and the alternative hypothesis Ha must be accepted.

In the section related to aflatoxin knowledge, differences between groups became more evident. Many respondents did not correctly recognize that aflatoxins are produced by fungi. Likewise, uncertainty was observed regarding the harmful effects of aflatoxins on human and animal health, the importance of controlling temperature and humidity during feed storage, and the transfer of aflatoxins from feed to milk and cheese. Group 1 generally showed higher scores than Group 2 for several of these items. A further misconception was observed for the statement that heat treatment reduces aflatoxin levels in cheese. This perception is problematic because AFM1 is relatively heat stable during routine dairy processing (Campagnollo et al. 2016; Gonçalves et al. 2022).

For sanitary management and hygiene, respondents strongly agreed about the importance of animal vaccination and periodic examinations for brucellosis and tuberculosis. However, significant differences were found between groups for cleaning of animal facilities, pest control, recognition of pest-related risks, and appropriate storage of cleaned utensils. These results suggested that general awareness of basic sanitary measures existed, but implementation-related perceptions differed considerably between producer groups, as also reported in studies on milk hygiene and farm management practices (Dereti et al. 2019; Nyokabi et al. 2021).

In the section on feed management, feed storage, and water quality, both groups generally agreed that water and feed provided to animals should be free from contaminants. Respondents also agreed that wells, springs, reservoirs, and water tanks should be protected and maintained adequately. Nonetheless, some items related to supplier approval, storage structure, and feed placement on the floor suggested gaps in technical understanding of preventive feed management. Because contaminated feed is the main entry point of AFB1 into the dairy chain, these weaknesses are relevant for AFM1 prevention in milk and cheese (Jiang et al. 2021; Xu et al. 2022; Yunus et al. 2022).

For milking and post-milking management, Group 1 tended to agree more strongly that the milking environment influences milk quality and that udder disinfection before and after milking is essential. Significant group differences were also observed for the black-background mug test and immediate milk cooling after milking. These findings indicated that important hygienic practices linked to milk safety were not uniformly recognized by all participants, although they are widely recommended for udder health and milk quality assurance (Morrill et al. 2019; Neculai-Valeanu and Ariton 2022; Nyokabi et al. 2021).

Finally, in the section related to workers' health, habits, and personal hygiene, Group 1 showed higher agreement than Group 2 for personal hygiene practices, clean uniforms, boots and aprons, and restrictions on inappropriate behaviors during milking. Field observations also suggested deficiencies in

nail hygiene, wound protection, clothing cleanliness, glove use, and periodic medical examinations. Together, these findings indicated that producers' general appreciation of hygienic practices did not always translate into specific knowledge or consistent implementation, which is consistent with previous reports on dairy hygiene practices among smallholders (Nyokabi et al. 2021; Korale-Gedara et al. 2023).

Overall, the study showed that dairy producers recognized the broad relevance of GAP, but important misconceptions remained regarding aflatoxins, preventive feed management, and hygienic practices related to milk and cheese safety. These gaps may compromise the adoption of effective preventive measures and may contribute to a higher risk of mycotoxin contamination in the dairy chain. Educational and extension initiatives directed at producers should therefore emphasize the causes of aflatoxin contamination, feed-to-milk carry-over, the persistence of AFM1 during processing, and the practical value of GAP for reducing both public health risks and economic losses (Xu et al. 2022; Yunus et al. 2022; Korale-Gedara et al. 2023).

Abbreviations

AFB1, aflatoxin B1; AFM1, aflatoxin M1; FA, factor analysis; GAP, good agricultural practices; HCA, hierarchical cluster analysis

Declarations

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Author contributions

Isabela Maria M. Silva: Conceptualization, methodology, validation, formal analysis, investigation, writing - original draft, writing - review and editing. Luzianna M. Fonseca: Methodology, validation, formal analysis, writing - original draft, writing - review and editing. Domingos Armando S. Jeque: Methodology, validation, formal analysis, writing - original draft, writing - review and editing. Tatiana C. Pimentel: Writing - original draft, writing - review and editing. Elson Rogério T. Filho: Database analysis. Gustavo L. de Paiva Anciens Ramos: Review and editing. Carolina P. Martins: Formal analysis and investigation. Erick A. Esmerino: Conceptualization, methodology. Adriano G. Cruz: Conceptualization, supervision and project administration. Rodrigo B. A. Oliveira: Investigation, supervision, project administration, writing - original draft, writing - review and editing. All authors read and approved the final manuscript.

Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval

The study was approved by the Research Ethics Committee involving Human Subjects of the Federal Rural University of Pernambuco (CAAE: 5354.204/2022) and was conducted in accordance with the applicable ethical standards.

Consent to participate

Informed consent was obtained from all individual participants included in the study.

Conflict of interest

The authors declare no conflict of interest.

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Figures

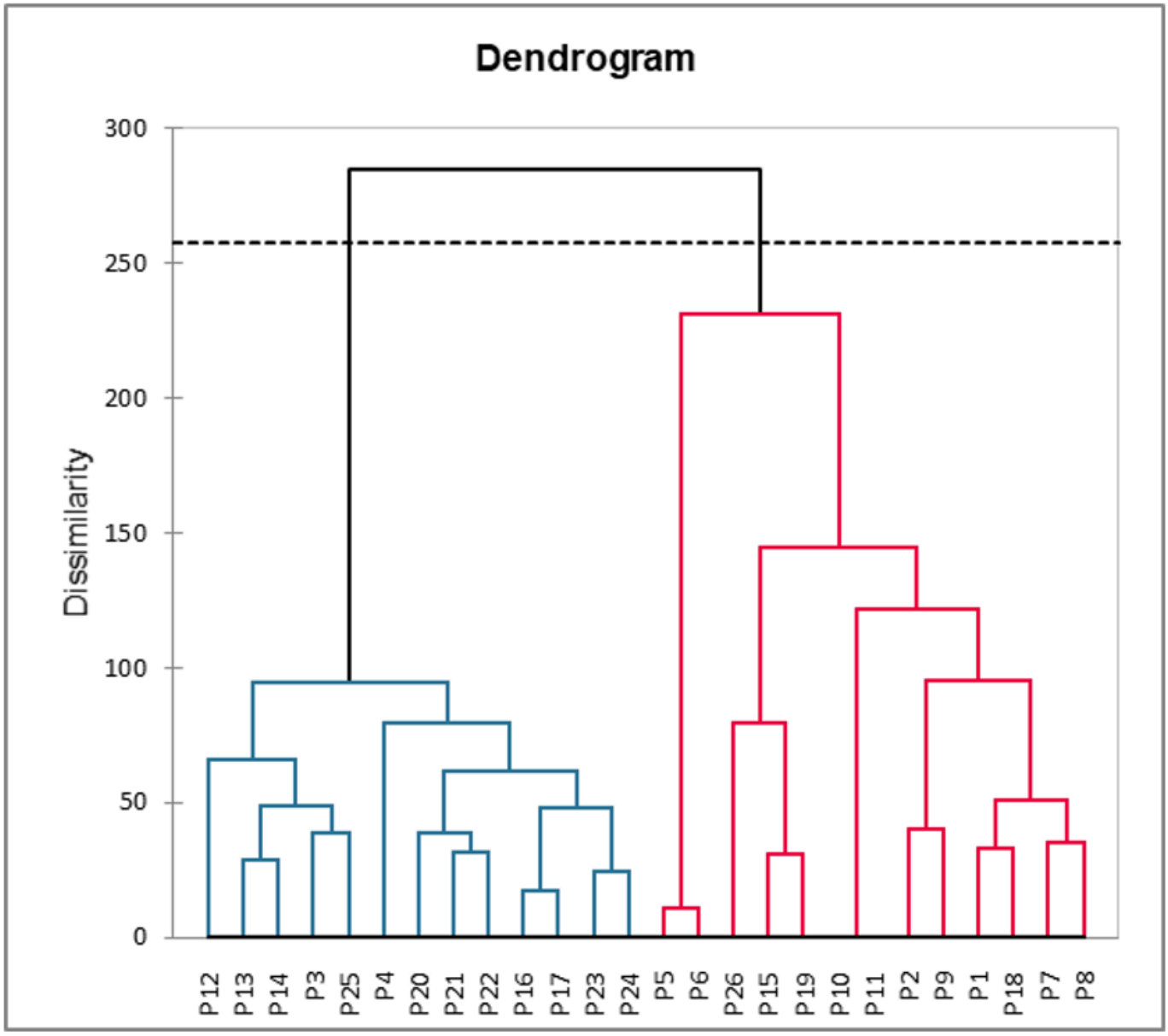


Figure 1

Dendrogram of the hierarchical cluster analysis (HCA) of dairy producers' response patterns