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Microbiological profile of paddy and commercial rice (*Oryza sativa* L) in the department of Norte de Santander, Colombia

Perfil microbiológico del arroz (Oryza sativa L*) tipo paddy y comercial en el departamento Norte de Santander, Colombia*

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Resumen

El arroz (Oryza sativa L.) es un alimento de gran importancia mundial y en Colombia es el tercer cultivo más extenso, con 25.000 hectáreas sembradas y una producción que supera las 180.000 toneladas anuales. Este estudio evaluó el perfil microbiológico del arroz cultivado y comercializado en el departamento de Norte de Santander, analizando 55 muestras de las principales zonas productoras (Cúcuta, El Zulia, Tibú y Puerto Santander). Se cuantificaron coliformes totales, *Escherichia coli*, aerobios mesófilos, mohos y levaduras. En arroz *paddy*, se encontraron altos niveles de coliformes totales (5,37 log UFC/g) y *E. coli* (3,23 log UFC/g), mientras que en arroz comercial estos valores cumplieron los estándares. Los recuentos de aerobios mesófilos y de mohos y levaduras fueron elevados tanto en arroz *paddy* como comercial. Estos resultados sugieren deficiencias en el manejo del agua de riego y el almacenamiento, lo que representa un riesgo para la salud pública por la posible producción de micotoxinas, destacando la necesidad de estrategias para garantizar la inocuidad del arroz.

Palabras clave: Análisis microbiológico, arroz, contaminación microbiana, seguridad alimentaria.

Abstract

Rice (*Oryza* sativa L.) is a globally important food, and in Colombia, it ranks as the third-largest crop, covering 25,000 hectares and yielding over 180,000 tons annually. This study assessed the microbiological profile of rice cultivated and marketed in the Norte de Santander department, analyzing 55 samples from the main production areas (Cúcuta, El Zulia, Tibú, and Puerto Santander). Total coliforms, *Escherichia coli*, mesophilic aerobes, molds, and yeasts were quantified. In *paddy* rice, high levels of total coliforms (5.37 log CFU/g) and E. coli (3.23 log CFU/g) were found, while in commercial rice, these values met the established standards. Counts of mesophilic aerobes and molds and yeasts were elevated in both paddy and commercial rice. These findings suggest deficiencies in irrigation water management and grain storage, posing a public health risk due to the potential production of mycotoxins. Therefore, effective strategies are needed to control microorganisms and ensure rice safety throughout the food supply chain.

Keywords: Microbiological analysis, rice, microbial contamination, food safety.

1. Introduction

Rice, as one of the most important food crops worldwide, plays a crucial role in global food security and nutrition [1, 2]. In Colombia, it ranks as the third-largest crop in terms of agricultural land area, with an average consumption of 43.2 kilograms per person per year [3]. Notably, there are significant differences between the diets of rural and urban households: the annual per capita consumption is 49 kilograms in rural households, compared to 41 kilograms in urban ones [3].

The rice produced in the department of Norte de Santander supplies both the domestic and international markets, thus contributing to the country's food security and generating significant income for local producers and traders [4]. Moreover, rice production plays a vital role in driving the regional economy, creating jobs at every stage of the value chain, from planting and harvesting to processing and commercialization.

Food safety and rice quality are of utmost importance due to its role as a staple food for a large part of the population in the region. However, both paddy rice and white rice are often stored under inadequate conditions in suboptimal facilities, which fosters contamination by microorganisms, particularly the proliferation of fungi [5, 7].

Microbiological contamination in grains such as rice can lead to the production of mycotoxins [8, 9]. Additionally, there is a risk of adulteration, which is often difficult to detect and poses a significant threat to human health [10]. Therefore, it is crucial to analyze and evaluate the safety and microbiological quality of food products to ensure both their safety and food quality [11].

The importance of rice cultivation in Norte de Santander contrasts with the limited attention given to scientific research and quality control policies in the region. The majority of studies have focused on agronomic and technological aspects, leaving a gap in the evaluation of the microbiological safety of the final product. This gap could have serious implications for public health and food security, as it hampers the identification of potential risks and the implementation of control measures. In this regard, it is necessary to conduct studies that explore and quantify the microbial groups present in rice, providing the information needed to improve agricultural practices and storage conditions for the cereal. In response to this need, this article presents the results of a study conducted with the support of Fedearroz (Cúcuta branch), which explores the microbiological quality of rice produced and marketed in the department of Norte de Santander during 2022.

2. **Materials and Methods**

2.1 Sample Collection

In this study, two types of samples were used: cultivated rice (paddy rice) and packaged rice distributed for consumption (commercial). A total of 40 paddy rice samples were evaluated, collected from the five municipalities with the highest production in the department of Norte de Santander. The sampling was distributed according to the cultivation zone and the area dedicated to it as follows: Cúcuta, 22 samples; El Zulia, 5 samples; Puerto Santander, 3 samples; and Tibú, 10 samples. Similarly, 15 samples of commercial rice were collected from the central market in Cúcuta, bringing the total number of analyzed samples to 55. The paddy rice sampling was conducted with the collaboration of Fedearroz, Cúcuta branch. Each sample was transported to the laboratory within 24 hours of collection for processing.

2.2 Microbiological Analysis

For the microbiological analysis, 11 grams of each sample were weighed and homogenized with 99 ml of 0.1% peptone water. From this solution, the appropriate procedure was applied according to the analysis.

2.2.1 Mesophilic Aerobes

This determination was carried out using the deep plate count method, following the guidelines of the Colombian Technical Standard NTC 4519 [12]. From the last two decimal dilutions (10^{-5} and 10^{-6}), 1 ml was transferred to sterile Petri dishes, and 15 ml of Standard Plate Count (SPC) agar (Merck) was added and mixed with the inoculum. This procedure was performed in duplicate for each dilution. The Petri dishes were incubated at 37°C for 24-48 hours.

2.2.2 Total Coliforms and Escherichia coli

The analysis followed the horizontal method described in the Colombian Technical Standard NTC 4458 [13]. Serial dilutions up to 10^{-5} and 10^{-6} were prepared, and 1 ml of each dilution was plated on Petri dishes with Chromocult medium, in duplicate. The plates were incubated at 35°C ± 2°C for 24-48 hours. Plates with 30-300 CFU/g were selected, and the counts were expressed as Log10 CFU/g.

2.2.3 Molds and Yeasts

The fungal population count followed the technique recommended by the National Institute of Health of Colombia and the International Commission on Microbiological Specifications for Foods [14]. From each consecutive dilution (10^-5 and 10^-6), 1 ml was transferred, in duplicate, to sterile Petri dishes. Then, 15 ml of melted OGY agar was added, carefully mixing the inoculum with the medium. Once the agar solidified, the plates were inverted and incubated at 25ºC ± 2ºC for 5 to 7 days.

3. Data Analysis

In the context of the research, Microsoft Excel was used as a tool for data processing and visualization. Additionally, descriptive statistical techniques, such as measures of central tendency, dispersion, and distribution, were applied for a more detailed analysis of data behavior. The results were expressed as Log10 colony-forming units (CFU) per gram of product.

4. Results and Discussion

4.1 Presence of Total Coliforms and E. coli in Paddy Rice

As shown in Figure 1, all paddy rice samples from Cúcuta and El Zulia contained total coliforms, while 90% of the samples from Tibú had this bacterial group. These results suggest a high incidence of coliforms in the rice. On the other hand, only 1 of the 3 samples from Puerto Santander was contaminated. It is important to note that the presence of total coliforms in cereals does not always imply a health risk, as not all coliforms are pathogenic [15]. However, their presence indicates deficiencies in cultivation practices, particularly those related to irrigation [16]. The total coliform counts in the analyzed samples ranged from 4.39 to 6.22 log CFU/g, with an average of 5.37 log CFU/g. Given the relationship between the number of coliforms and the fecal origin of contamination, these high counts suggest the presence of fecal coliforms in paddy rice.

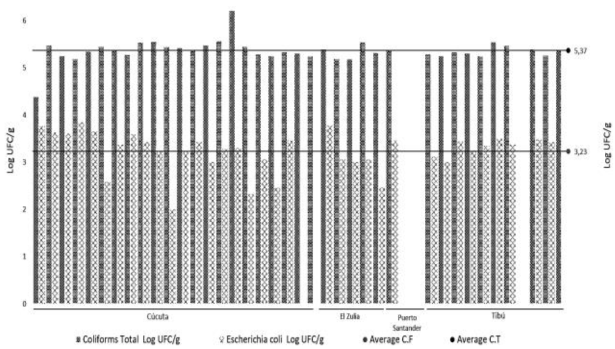

Figure 1. Presence of Total Coliforms and E. coli in Paddy Rice.

In analyzing the presence of fecal coliforms, it was found that 94.6% of all samples positive for total coliforms were contaminated with E. coli. This corroborates the high correlation between the presence of total and fecal coliforms [17]. On the other hand, E. coli counts varied between 2.0 and 3.85 log CFU/g, with an average of 3.23 log CFU/g, reflecting considerably high levels compared to those required for cereals according to Resolution 1407 of 2022 from the Ministry of Health and Social Protection, which establishes a value of <10 CFU/g [18].

Samples with the highest levels of total coliforms and E. coli were taken from crops in Cúcuta. The presence of fecal coliforms is an indicator of the quality of water used in the irrigation system [19]. In Norte de Santander, the El Zulia irrigation district, located in the valleys of the Zulia and Pamplonita rivers, is of great importance due to its use as a water source for capturing, recreation, and agricultural and livestock activities. However, in some areas, these rivers are used as dumping sites for domestic and agro-industrial wastewater, leading to their contamination. The values of fecal coliforms reflect the bacterial load of the effluents, which also receive municipal discharges along their course, making self-purification processes difficult [20].

Previous studies have reported the presence of fecal coliforms in water, attributing the elevated levels of this microbial group to dry periods, which cause their concentration in the samples [21]. Likewise, in the points with the highest counts, anthropogenic activities such as agriculture, livestock, recreation areas, and discharge of effluents were observed, among others [22]. On the other hand, the presence of fecal contamination in this cereal highlights a potential risk of contamination with enteric pathogens, so preventive measures should be taken to ensure food safety. The high incidence of total coliforms in paddy rice suggests greater vulnerability to microbial contamination during the cultivation and post-harvest phases. In contrast, commercial rice should present a safer microbiological profile due to control measures during processing. It is relevant to improve management practices in the cultivation of paddy rice to reduce the risk of fecal contamination, which would also benefit the quality of the final product in the market. This analysis underscores the importance of microbiological monitoring at various stages of rice production to ensure food safety.

4.1.2 Mesophilic Aerobes in Paddy Rice

Upon analyzing the results, it was observed that mesophilic aerobes ranged between 4.62 and 6.33 log CFU/g (Fig. 2). These data demonstrate a wide variation in bacterial contamination levels in paddy rice samples, with differences of up to two logarithmic units.

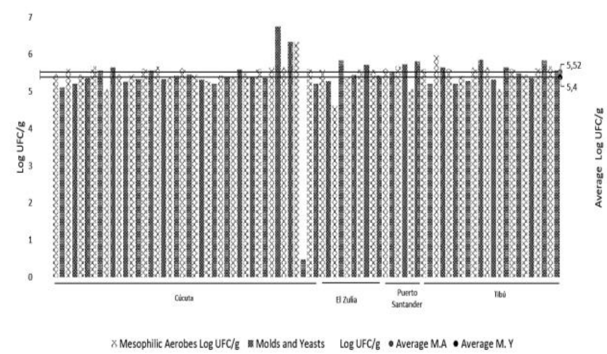

Figure 2. Counts of mesophilic aerobes and molds and yeasts in paddy rice.

Mesophilic aerobes are an indicator group of the degree of bacterial contamination in food. Their presence in paddy rice is expected, as this product is exposed to the environment and sensitive to climate variations during the cultivation and harvesting process. Therefore, the results reflect the changes in environmental conditions to which the grain was exposed. However, when high concentrations are recorded, they may be related to environmental contamination, improper handling, or storage failures [23]. Consequently, it is essential to reduce the levels of mesophilic aerobes by implementing control measures during the production stages of paddy rice.

4.1.3 Mold and Yeast Levels in Paddy Rice

This microbiological variable provides essential information about the environmental conditions during cultivation; however, unlike mesophilic aerobes, molds and yeasts not only act as indicators but can also alter and/or modify the quality properties of the grain [24]. Understanding the incidence of fungi in rice is important, as some genera produce mycotoxins, continuous exposure to which can pose serious risks to human and animal health [25]. Additionally, fungal proliferation is one of the main causes of rice grain deterioration [26].

Therefore, molds and yeasts constitute a microbiological variable of great importance, both from the perspective of quality and food safety. In this study, it was observed that, as in the case of mesophilic aerobes, high counts were recorded in most samples (Fig. 2). The greatest variation in fungal population concentration was detected in samples from Cúcuta, where levels reached up to 6.75 log CFU/g, indicating extremely high fungal contamination. High levels of fungi in cereals are more common in regions with warm and humid climatic conditions, such as the sampled areas. Furthermore, if rice is harvested with high moisture levels, it facilitates the development of this group of microorganisms [25]. This implies that the periods between harvesting and drying the rice are a critical factor directly influencing fungal growth. Fungi can adapt to the conditions of cereal grains and proliferate on their surface.

When rice is affected by fungal contamination on the husk, fungi can penetrate the grain's endosperm during cultivation or storage, which not only results in economic losses but also compromises food safety [26]. As a result of fungal growth on the grain, fungi can produce and release toxic metabolites for consumers [27].

4.2 Microbiological Quality of Commercial Rice

For the analysis of commercial rice, the results obtained were compared with the parameters established in the technical specifications sheet of the National Federation of Rice Growers (Fedearroz). According to this document, rice must meet certain microbiological specifications, including: absence of E. coli, a total coliform count below 0.48 log CFU/g, mesophilic aerobe levels of no more than 5.48 log CFU/g, and a total mold and yeast count below 3.7 log CFU/g.

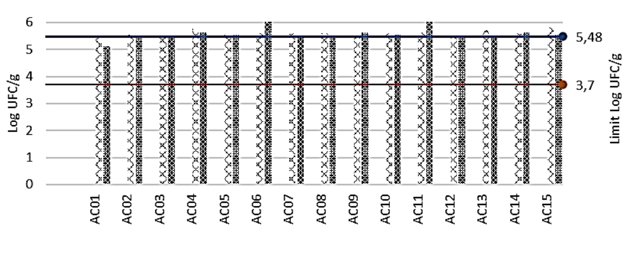

Figure 3. Microbiological Analysis of Commercial Rice.

First, the absence of total coliforms and E. coli in all samples (<0 log CFU) was confirmed. This result highlights that post-harvest handling processes, including de-husking in mills, have a positive impact on the elimination of coliforms, suggesting that these bacteria are primarily associated with the grain's outer layers (lemma and palea) [28]. Furthermore, it reflects the implementation of good sanitary and post-harvest handling practices, which should be maintained [29]. Commercial rice typically undergoes cleaning, drying, and packaging processes that significantly reduce the microbial load, including the presence of coliforms [30].

On the other hand, Figure 3 shows that mesophilic aerobes were within a narrow range (5.52–5.76 log CFU/g), with an average of 5.60 log CFU/g, slightly exceeding the reference limit. Although, in general, commercial rice in Norte de Santander meets the threshold established in the Fedearroz technical sheet, it is necessary to monitor rice storage and handling conditions to avoid unexpected increases in bacterial load. It is known that the proliferation of mesophilic aerobes in stored grains is influenced by factors such as water activity (Aw), humidity, and temperature. Previous research has demonstrated that controlling these parameters is key to limiting bacterial growth in stored products such as rice [29, 30].

Regarding molds and yeasts, values ranged between 5.11 and 6.3 log CFU/g, with an average of 5.60 log CFU/g (Figure 3). These results significantly exceed the permitted limit, by approximately 100 times. When comparing mold and yeast levels between paddy rice and packaged rice, it is observed that they remain practically constant. This indicates that, unlike coliforms, post-harvest and grain storage processes had no reductive effect on the fungal population. This confirms the previously mentioned food safety risk when discussing mold and yeast data in paddy rice. The excess fungal population reflects both cultivation and storage conditions that allow for their survival, making it necessary to identify the causes and take corrective measures.

It is worth noting that the characteristics of stored grain may limit the growth of certain types of microorganisms but favor others, such as molds in stored rice. This group of microorganisms includes xerophilic species that are well-adapted to substrates with low Aw and moisture content, such as cereals [29, 31]. Therefore, the parameters that control the bacterial population are not equally effective with fungi. For this reason, as previously mentioned, the presence of molds and yeasts is a highly relevant parameter since it implies the risk of product contamination by mycotoxins [32, 33]. For this reason, various studies emphasize the importance of implementing control and monitoring programs to prevent the development of molds and yeasts in this type of cereal [34, 35].

Regarding post-harvest practices, it is recommended to adopt storage protocols that include humidity control, proper ventilation, and the maintenance of optimal temperatures. These measures help reduce microorganism proliferation and prevent cross-contamination between rice batches. Additionally, implementing risk management systems such as Hazard Analysis and Critical Control Points (HACCP) is key to identifying and controlling microbiological hazards throughout the rice production and storage chain.

Conclusions

High levels of total coliforms and E. coli were recorded in paddy rice, highlighting deficiencies in agricultural practices. In particular, attention should be given to irrigation water, presumed to be the main source of contamination by this group of bacteria. Various water treatment techniques can be implemented to mitigate this risk, such as filtration systems, which help remove particles and microorganisms from the water before its application in rice cultivation. Another preventive measure is controlled chlorination, which effectively eliminates pathogenic bacteria from irrigation water, provided it is used safely and regulated. Furthermore, it is essential to establish a continuous monitoring system of water quality through regular analysis of microbiological and physicochemical parameters to ensure it meets safety standards. As for commercial rice, it meets established standards regarding total coliforms and E. coli, suggesting that post-harvest handling processes were effective in eliminating this bacterial group. The mesophilic aerobe counts in paddy rice were within expected ranges, and in commercial rice, they were within permitted limits. This parameter showed the most favorable behavior. High counts of molds and yeasts were observed in both paddy rice and commercial rice, with no significant difference between the two. Therefore, it is presumed that grain processing did not have a notable impact on the concentration of this population. These results reveal a potential food safety risk due to the possibility of mycotoxins being produced in the grain.

Since rice is a staple in the diet, contamination of this cereal represents a significant challenge to public health. Therefore, it is essential to develop strategies aimed at controlling the presence of fungi and other microorganisms that pose a risk to grain safety and could affect consumer health.

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