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THE IMPACT OF STORAGE CONDITIONS ON THE MICROBIOLOGICAL AND ORGANOLEPTIC QUALITY OF COOKED RICE

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Abstract. Cooked rice, owing to its high moisture content and rich nutritional profile, is particularly prone to microbiological contamination, especially under suboptimal storage conditions. This study investigated the effects of three distinct storage regimes—room temperature, refrigeration, and freezing—on the microbiological and organoleptic quality of cooked rice, with the objective of identifying safe consumption windows and minimizing quality degradation. Microbiological assessments were carried out in accordance with relevant ISO standards, while sensory evaluation was performed using a descriptive scoring method by a trained panel. The findings revealed that rice stored at room temperature became microbiologically unsafe after 24 hours. In contrast, refrigeration maintained microbiological safety up to day five, and freezing preserved overall stability for up to three months. However, sensory quality deteriorated progressively under all conditions, with the most pronounced alterations observed in samples frozen for over 90 days. These results underscore the critical role of appropriate storage conditions in ensuring food safety and preserving sensory attributes. While the study does not propose technological innovations, it provides a practical framework by integrating microbiological and sensory evaluations into a reproducible model applicable in both educational and professional settings.

Keywords: *cooked rice, storage conditions, refrigeration, freezing, microbiological analysis, sensory evaluation, food safety.*

Rezumat: Orezul gătit, datorită conținutului său ridicat de umiditate și profilului său nutrițional bogat, este deosebit de predispus la contaminare microbiologică, în special în condiții suboptime de depozitare. Acest studiu a investigat efectele a trei regimuri distincte de depozitare — temperatura camerei, refrigerare și congelare — asupra calității microbiologice și organoleptice a orezului gătit, având ca obiectiv identificarea ferestrelor de consum sigur și minimizarea degradării calității. Evaluările microbiologice au fost realizate în conformitate cu standardele ISO relevante, iar evaluarea senzorială a fost efectuată utilizând o metodă descriptivă de scor de către un panel instruit. Rezultatele au evidențiat că orezul păstrat la temperatura camerei a devenit nesigur din punct de vedere microbiologic după 24 de ore. În schimb, refrigerarea a menținut siguranța microbiologică până în ziua a cincea, iar congelarea a asigurat stabilitatea generală pentru o perioadă de până la trei luni. Totuși, calitatea senzorială s-a deteriorat progresiv în toate condițiile, cele mai pronunțate modificări

fiind observate în probele congelate mai mult de 90 de zile. Aceste rezultate subliniază rolul esențial al condițiilor adecvate de depozitare în asigurarea siguranței alimentare și conservarea caracteristicilor senzoriale. Deși studiul nu propune inovații tehnologice, el oferă un cadru practic prin integrarea evaluărilor microbiologice și senzoriale într-un model reproductibil, aplicabil atât în mediul educațional, cât și în cel profesional.

Cuvinte-cheie: *orez gătit, condiții de depozitare, refrigerare, congelare, analiză microbiologică, evaluare senzorială, siguranța alimentelor*.

1. Introduction

Rice is one of the most widely consumed foods globally, serving as an essential source of carbohydrates, proteins, and micronutrients for more than half of the world's population [1]. It is also often cooked in advance and stored for later consumption, which can significantly influence both its nutritional value and food safety [2].

The quality of cooked rice is affected by factors such as temperature, humidity, and storage duration, which directly influence the development of microflora and the occurrence of physicochemical changes [3]. Due to its high-water content and carbohydrate-rich composition, cooked rice becomes a favorable substrate for microbial growth, especially when stored at room temperature [4]. The presence of pathogenic agents such as *Bacillus cereus* is well documented in the literature under these conditions and is frequently associated with foodborne illnesses [5].

On the other hand, refrigeration and freezing are effective methods for slowing microbial growth, but they can negatively impact the sensory properties of the product through processes such as starch retrogradation, texture modification, and flavor loss [6]. Studies indicate that prolonged storage can lead to changes in consistency, aroma, and appearance, affecting the overall acceptability of the product [7,8].

In this context, the present study aims to analyze the impact of storage conditions on the microbiological and organoleptic quality of cooked rice. The study compares three experimental conditions (room temperature, refrigeration, and freezing) to determine optimal storage intervals from the perspective of food safety and sensory acceptability.

2. Materials and Methods

The following materials were used in the study:

- Round-grain rice groats (*Bunetto* brand, code SM 1004), commercially available, with fine granulation and a high starch content, suitable for preparing a liquid-consistency porridge.
- Purified, still drinking water (*OM* brand), certified in accordance with the FSSC 22000 standard.
- Cooked rice, obtained according to the protocol described below, portioned and stored in sterile containers.
- Experimental samples of cooked rice, cooled and subsequently stored under different temperature regimes for varying durations.
- Culture media and laboratory reagents, used for microbiological analyses, in accordance with the ISO standards referenced in Section 2.4.

2.1.2. Protocol for Thermal Processing

The cooking process was conducted under standardized conditions, as outlined in Table 1.

Table 1

Standardized boiling conditions applied to cooked rice samples

Parameter	Specification
Type of rice	Round-grain rice
Water-to-rice ratio	2:1
Cooking vessel	Stainless steel pot, 22 cm diameter
Final consistency	Liquid (soft porridge)
Cooking method	Boiling on stovetop, uncovered
Boiling temperature	100°C

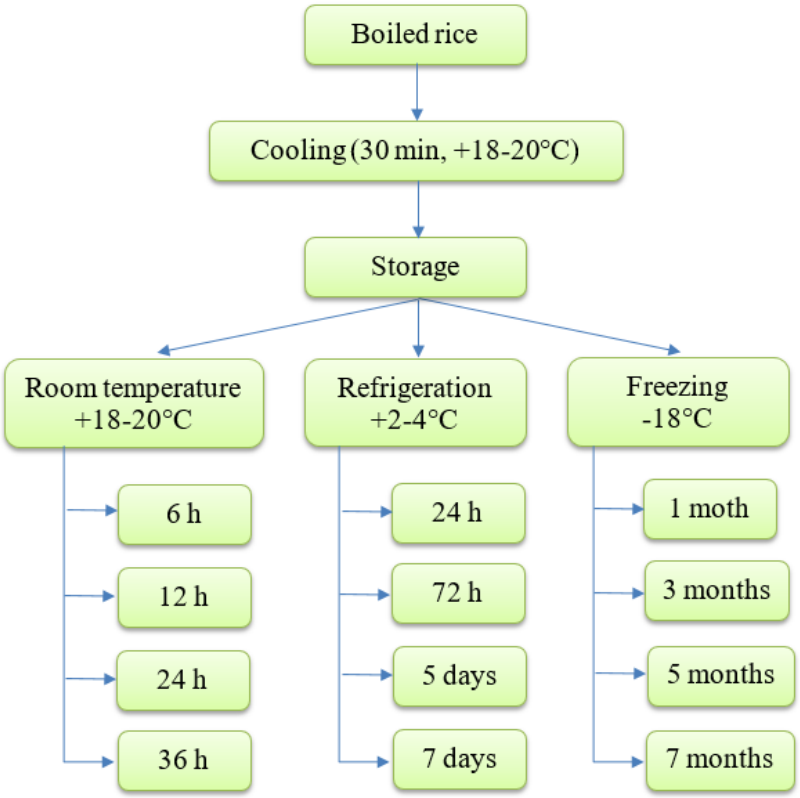


Figure 1. Storage Scheme of Boiled Rice Based on Thermal Regime.

After boiling, the rice was left to cool for 30 minutes at room temperature (+18...+20°C) in a hygienic environment, uncovered, to allow for texture stabilization.

2.1.3. Storage Protocol

Cooked rice samples were divided into equal batches and stored in sterile, airtight containers. Three temperature regimes were used for storage, as follows:

- Room temperature (+18...+20°C): 6 hours, 12 hours, 24 hours, and 36 hours.
- Refrigeration (+2...+4°C): 24 hours, 72 hours, 5 days, and 7 days.
- Freezing (−18°C): 1 month, 2 months, 3 months, and 5 months.

The batches were subsequently evaluated from both microbiological and organoleptic perspectives at each time point. The storage process is illustrated schematically in Figure 1.

2.2. Laboratory Equipment and Materials

The following equipment and consumables were used in the experiment, all compliant with good laboratory practice requirements (Table 2) [9,10].

Table 2

Equipment and consumables used for the preparation, storage, and analysis of cooked rice samples

Equipment	Model / Brand	Country of Origin	Purpose
Precision scale	Kern FCB 6K1	Germany	Accurate weighing of ingredients and sample portions
Microwave oven	Samsung MG23K3575AS	South Korea	Uniform reheating of samples (if applicable)
Laboratory refrigerator	Liebherr TP 1410	Germany	Storage of samples at controlled temperature (+2…+8 °C)
Vertical freezer	Liebherr GP 1486	Germany	Storage of samples at −18 °C
Bacteriological incubator	Unspecified model	-	Incubation of Petri dishes at 30 °C and 37 °C
Laminar flow microbiological cabinet	Unspecified model	-	Aseptic handling during inoculation
Digital thermometer	Unspecified model	-	Temperature monitoring during sample storage
Culture media (PCA, VRBL, XLD, Baird-Parker)	Merck, Bio-Rad	Germany, France	Microbiological determinations in accordance with ISO standards [11,13–15]

All disposable materials were sterilized prior to use or supplied in a sterile state. The culture media were prepared according to the manufacturers' instructions [11] and used in compliance with the ISO standards specific to each type of analysis [12-15].

2.3. Sample Storage Protocol

After boiling, the rice was allowed to cool at room temperature (+18…+20°C) for 30 minutes, uncovered, under controlled hygienic conditions. The samples were then portioned into sterile, single-use food-grade plastic containers, sealed tightly, and properly labeled.

According to the analytical objectives, the samples were divided into three experimental batches, each subjected to a distinct storage regime:

- At room temperature (+18…+20 °C): evaluation was performed after 6, 12, 24, and 36 hours.
- Under refrigeration (+2…+4 °C): samples were analyzed after 24 hours, 72 hours, 5 days, and 7 days.
- Under freezing (−18 °C): evaluation was conducted after 1 month, 2 months, 3 months, and 5 months.

All samples were stored in designated spaces, without significant variations in temperature or exposure to light. Storage was carried out without opening the containers until the time of microbiological and organoleptic testing.

The overall structure of the experimental design is illustrated schematically in Figure 1.

2.4. Analytical Methods

To assess the influence of storage conditions on product quality, the cooked rice samples were analyzed from both microbiological and organoleptic perspectives, in accordance with internationally recognized protocols. The analytical methods were systematically applied to all experimental batches in parallel, using equipment and materials compliant with food safety standards.

2.4.1. Microbiological Analysis

Microbiological determinations were carried out in accordance with international ISO standards, using both selective and non-selective culture media, as specified in Table 3. All samples were processed under aseptic conditions, employing a laminar flow microbiological cabinet and sterile materials. Results were expressed in colony-forming units (CFU/g), and interpretation was performed in compliance with Regulation (EC) No 2073/2005 on microbiological criteria for foodstuffs.

Table 3

Applied microbiological methods and incubation conditions

Target Microorganism	Culture Medium	Incubation Conditions	Reference Standard
Total viable count (TVC)	Plate Count Agar (PCA)	30 °C for 72 h	ISO 4833-1:2013 [13]
Enterobacteriaceae	Violet Red Bile Glucose Agar (VRBL)	37 °C for 24 h	ISO 21528-2:2017 [14]
Salmonella spp.	Xylose Lysine Deoxycholate Agar (XLD)	37 °C for 24 h	ISO 6579-1:2017 [15]
Staphylococcus aureus (coagulase-positive)	Baird-Parker Agar	37 °C for 48 h	ISO 6888-1:2021 [16]

2.4.2. Organoleptic Evaluation

The organoleptic analysis was conducted in accordance with the SR ISO 6658:2017 standard on sensory analysis methodology, using the descriptive scoring method. The evaluation was carried out in a dedicated, well-lit room, free of extraneous odors, and maintained at a constant ambient temperature.

The tasting panel consisted of 10 individuals aged between 22 and 60 years, previously familiarized with the analyzed product and the scoring methodology. Each participant received coded samples of cooked rice from all experimental batches, served in single-use containers at the optimal temperature for tasting.

The reference attribute was overall sensory quality, assessed based on four criteria: visual appearance, aroma, taste, and texture. Each criterion was rated on a scale from 1 (unsatisfactory) to 5 (excellent). The final score was expressed as the arithmetic mean of the ratings given by all panelists for each criterion and each individual sample.

Samples were presented in random order to minimize psychological bias. Between samples, panelists used still water to cleanse the palate.

3. Results and Discussion

3.1. Evolution of Microbial Load Depending on Storage Regime and Duration

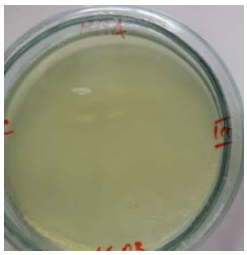
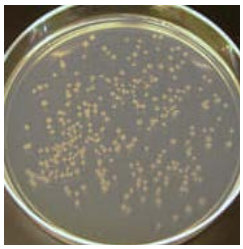
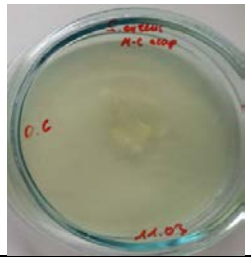
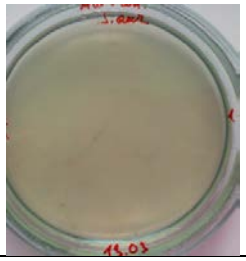
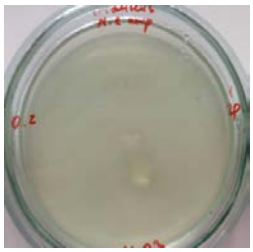
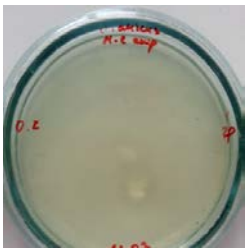
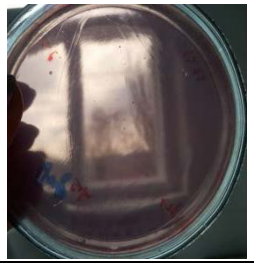
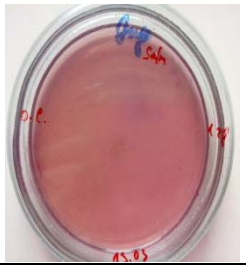
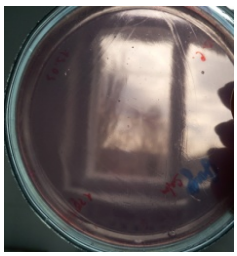
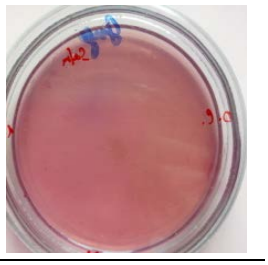
The evolution of the microbiological quality of cooked rice was analyzed based on the applied storage conditions and the duration of storage. The analyses focused on the presence and

dynamics of mesophilic aerobic and facultative anaerobic flora, coliforms, *Staphylococcus aureus* bacteria, and *Salmonella spp.* strains, for each of the experimental batches evaluated.

Under room temperature storage conditions (+18...+20°C), an increase in mesophilic aerobic flora was observed as early as the first 12 hours, from <10 CFU/g to 3.4×10^2 CFU/g. After 24 hours, the values exceeded the acceptable limit (1.1×10^3 CFU/g), reaching 2.1×10^3 CFU/g at 36 hours. The detailed evolution of the microbial load is presented in Table 4. During this period, coliforms, *Staphylococcus aureus*, and *Salmonella spp.* we're not detected.

Table 4

Microbiological Results for Cooked Rice Stored at Room Temperature

Admissible Limit (According to Regulation EC No. 2073/2005)	**Mesophilic Aerobic and Facultative Anaerobic Bacteria (CFU/g)**	**Coliform Bacteria (in 0.01 g of product)**	**Staphylococcus aureus (in 1 g of product)**	**Salmonella spp. (in 25 g of product)**
	⩽ 1.0×10^3	**Absence**	**Absence**	**Absence**
Storage Duration	<10	Not detected	Not detected	Not detected
6 hours				
12 hours	3.4×10^2 	Not detected 	Not detected 	Not detected 
24 hours	1.2×10^3 	Not detected 	Not detected 	Not detected 
36 hours	2.1×10^3 	Not detected 	Not detected 	Not detected 

Under refrigeration conditions (+2…+4 °C), the evolution of the microbial load was significantly slowed. Values remained within admissible limits until the fifth day; however, on the seventh day, the critical threshold (1.5×10^3 CFU/g) was exceeded, and coliform colonies appeared, indicating the onset of spoilage. No pathogenic microorganisms were detected during this period.

Under freezing conditions (−18 °C), the samples remained microbiologically stable up to the third month. After this period, the bacterial load began to gradually increase, reaching 2.5×10^3 CFU/g by the fifth month, thus exceeding the maximum admissible limit. Throughout the entire freezing period, no presence of coliforms, *Salmonella spp*., or *Staphylococcus aureus* was detected (Table 5).

Table 5

Microbiological Results for Cooked Rice Stored Under Refrigeration and Freezing Conditions

Storage Regime	Storage Duration	Mesophilic Aerobic and Facultative Anaerobic Bacteria (CFU/g)	Coliform Bacteria (in 0.01 g of product)	*Staphylococcus aureus* (in 1 g of product)	*Salmonella* spp. (in 25 g of product)
Refrigeration (+2…+4°C)	24 h	<10	Not detected	Not detected	Not detected
Refrigeration (+2…+4°C)	3 days	5.0×10^2	Not detected	Not detected	Not detected
Refrigeration (+2…+4°C)	5 days	8.0×10^2	Not detected	Not detected	Not detected
Refrigeration (+2…+4°C)	7 days	1.5×10^3	Detected	Not detected	Not detected
Freezing (−18°C)	1 month	<10	Not detected	Not detected	Not detected
Freezing (−18°C)	2 months	<10	Not detected	Not detected	Not detected
Freezing (−18°C)	3 months	4.5×10^2	Not detected	Not detected	Not detected
Freezing (−18°C)	5 months	2.5×10^3	Not detected	Not detected	Not detected

The obtained results highlight the essential role of storage temperature in controlling the development of spoilage microflora in cooked rice. The rapid increase in mesophilic flora at room temperature is correlated with favorable conditions for bacterial growth (high humidity, neutral pH, and optimal temperature for development). These findings are consistent with previous studies, which indicate accelerated spoilage of rice-based preparations left at ambient temperature for more than 6–12 hours [17,18].

The microbiological stability observed under refrigeration up to day five is a positive outcome; however, the presence of coliforms on day seven confirms that refrigeration slows but does not entirely inhibit bacterial growth. Freezing, while effective in maintaining a low microbial load in the medium term, does not completely prevent long-term bacterial proliferation—likely due to the reactivation of bacteria after thawing and structural degradation of the samples.

The systematic absence of major pathogenic agents (*Salmonella spp.* and *Staphylococcus aureus*) may indicate good hygiene practices during preparation and handling, but this cannot be generalized beyond controlled laboratory conditions.

These data support the practical recommendation to consume cooked rice within 24 hours if stored at room temperature, within 5 days if refrigerated, or within 3 months if frozen—under optimal hygienic conditions.

3.2. Evolution of Organoleptic Characteristics Depending on Storage Conditions

The sensory analysis aimed to assess how the appearance, aroma, taste, and texture of cooked rice change depending on the storage regime and duration. The evaluation was performed by a panel of 10 trained individuals, using a five-point scale for each sensory attribute, where 5 represented excellent quality and 1 indicated an unacceptable product.

Storage at room temperature. After 12 hours, the samples were rated as having acceptable sensory characteristics. However, starting from 24 hours, a clear decline in organoleptic quality was observed, particularly in terms of aroma and taste, which received average scores of 2.8 and 2.5, respectively. After 36 hours, all four attributes scored below 2, with the appearance becoming wet and unattractive, the texture sticky, and the aroma noticeably altered (Figure 2. Results of the sensory evaluation of cooked rice stored at room temperature).

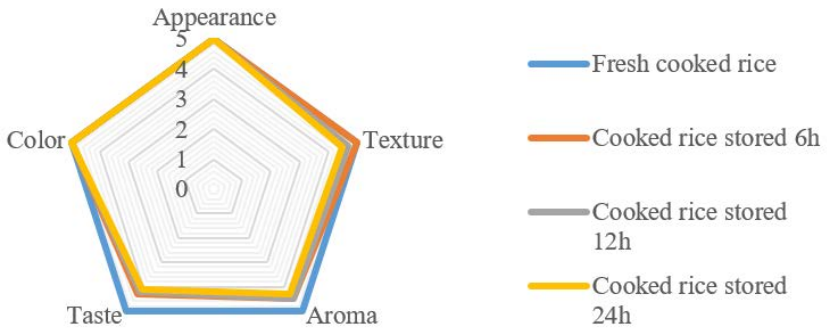


Figure 2. Results of the sensory evaluation of cooked rice stored at room temperature.

Refrigeration Regime (+2...+4 °C). Samples stored under refrigeration and evaluated after 24 hours maintained good sensory quality, with scores above 4 for all attributes. Slight declines were observed on days three and five, particularly in aroma and taste. After 7 days, the taste was considered slightly altered, and the texture was perceived as wetter compared to fresh samples. The scores decreased to average values between 2.9 and 3.2 (Figure 3. Results of the sensory evaluation of cooked rice stored under refrigeration conditions).

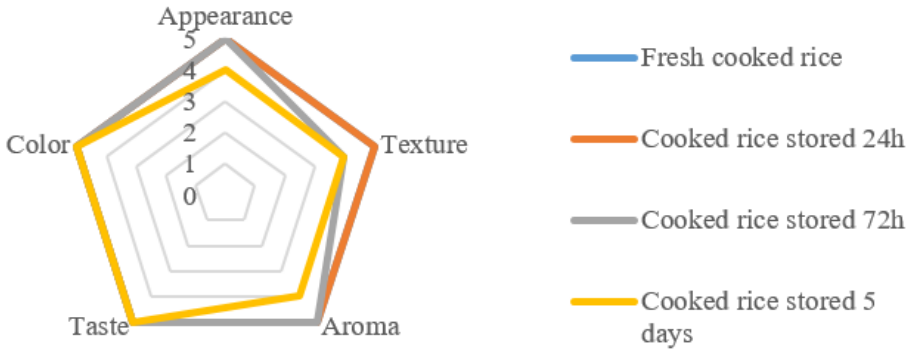


Figure 3. Results of the sensory evaluation of cooked rice stored under refrigeration.

Freezing Regime (–18 °C). Freezing allowed for the preservation of sensory characteristics for up to two months, with scores ranging between 4.0 and 4.5. In the third month, the panel observed a decline in texture and a slight loss of flavor, while in the fifth month, the changes were pronounced: the texture became soft and watery, the taste was bland, and the overall appearance was unsatisfactory. Scores dropped below 3 for all attributes, indicating advanced deterioration (Figure 4).

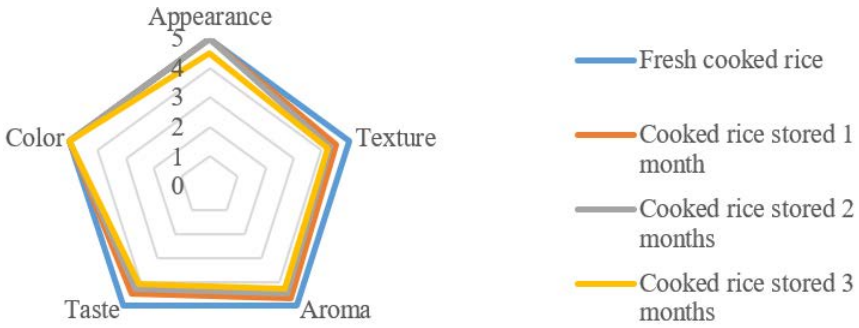


Figure 4. Results of the sensory evaluation of cooked rice stored at freezing temperature (–16...–18 °C).

The obtained data suggest that sensory changes are influenced by physicochemical reactions occurring during storage, particularly starch retrogradation and moisture migration. The results are consistent with previous research [19,20], which showed that rice-based foods are highly sensitive to textural and aromatic alterations during cold storage. Freezing best preserves the sensory profile during the initial months; however, cumulative negative effects become clearly noticeable after 90 days, especially in terms of taste and texture.

Considering these observations, it is recommended that cooked rice be consumed within 24 hours if stored at room temperature, within 3–5 days under refrigeration, and within a maximum of 2 months if frozen, in order to ensure acceptable sensory quality.

4. Conclusions and Recommendations

The results obtained in this study highlight the significant influence of storage conditions on the microbiological and organoleptic quality of cooked rice.

From a microbiological perspective, it was found that rice becomes unsafe for consumption after 24 hours of storage at room temperature due to the exceeding of permissible limits for mesophilic flora. Under refrigeration, microbiological safety is maintained up to the fifth day, while freezing ensures microbiological stability up to the third month. The presence of coliforms on day seven (refrigeration) and the increase in mesophilic load in the fifth month (freezing) indicate the onset of spoilage.

The sensory analysis confirmed the gradual degradation of organoleptic quality, reflected in the loss of aroma and taste, as well as changes in texture. The most affected samples were those stored under freezing conditions for more than 90 days, where starch retrogradation led to compacted texture and diminished flavor.

Based on the results obtained, the following maximum storage durations for cooked rice are recommended:

- up to 24 hours at room temperature (+18...+20 °C);
- up to 5 days under refrigeration (+2...+4 °C);
- up to 3 months under freezing (–18 °C), in sterile containers with no intermediate opening.

The results provide valuable scientific support for optimizing cooked rice storage practices, contributing to reduced food waste and increased consumer safety. These findings are relevant not only for households but also for catering units, public institutions, and operators in the food industry.

Although the study does not propose methodological or technological innovations, its merit lies in its practical synthesis of the effects of storage conditions on a widely consumed food, under controlled laboratory conditions. The work offers a simple model for combined microbiological and sensory evaluation, with didactic and practical applicability, which can be used in educational activities as well as to guide consumers toward safer storage practices.

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Conflicts of Interest: The authors declare no conflict of interest.

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