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Research Article

A Preliminary Study on the Use of Rice Husk-Based Smoke Powder for Meatball Preservatives

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This study examines the use of smoke powder derived from rice husks as a preservative for chicken meatballs. Rice husks were pyrolyzed in a slow pyrolysis reactor at the temperatures of 300°C (T1), 350°C (T2), and 400°C (T3) to produce liquid smoke. Each of the liquid smoke was distilled at 190°C and then converted into smoke powder by spray drying method. The smoke powder's feasibility as a meatball preservative was examined by total plate count (TPC), total volatile base (TVB), most probable number (MPN) test of *E. coli*, and organoleptic (aroma, texture, and color) tests. The results showed that the TPC and TVB increased with storage time. At the storage time of 76 hours, the meatballs were no longer suitable for consumption as the TPC had exceeded the minimum limit. In meatballs with T3 smoke powder at 72-hour storage, the number of colonies was 6.87×10^4 CFU/g, indicating the TPC value has not exceeded the threshold yet. The TVB test showed that up to 72 hours of storage, the meatballs remained fresh with a TVB value of less than 0.20 mgN/g. The result of the organoleptic test also showed that meatballs could last for 72 hours. The MPN test, on the other hand, revealed that the *E. coli* was still permissible after 68 hours of preservation.

1. Introduction

In recent years, liquid smoke from various biomass wastes including coconut shells [1, 2], white lead wood [3], aromatic plants [4], durian husks [5], sawdust [6], and cocoa pod [7] has been used as a preservative in wood and food products. The raw material commonly used to produce liquid smoke is biomass with a hard texture. In general, biomass contains about 50% cellulose, 25% hemicellulose, and 25% lignin [8]. Several studies attempted to utilize agricultural biomass wastes such as corn cobs, sugarcane stalks, and oil palm waste to produce energy or other useful materials [9, 10]. However, the use of biomass waste, especially rice husks, to produce liquid smoke has not attracted much interest among researchers, even though rice husks have untapped large potential or have not been used properly. A rice milling produces about 25% husk which is usually burned to produce biochar, boiler feed, cement filler [11–13], or used as an agricultural soil mixture.

Rice husk contains cellulose (about 32%), hemicellulose (21%), lignin (21%), ash (15%), and crude protein [14–16], which can produce quality liquid smoke [17]. Liquid smoke compounds from rice husks are reported to have several functional properties such as antibacterial/microbial [18, 19], antidiabetic [20], and anti-inflammatory [21], making them an alternative preservative for various food products. The organic acids in liquid smoke make its pH low, causing damage to the bacterial cell wall. In addition, liquid smoke also gives the effect of distinctive smoky flavor and appearance in food products [22].

Previous studies have examined the use of liquid smoke as a preservative for meat [23, 24] and tuna flesh [25]. However, the development of liquid smoke into smoke powder for food preservatives has not been widely carried out despite the method's convenience and ability to maintain liquid smoke quality. Powdered liquid smoke can maintain the stability of bioactive compounds in liquid smoke [26]. This study aims to examine the use of smoke powder from rice husks prepared at various pyrolysis temperatures as a preservative for chicken meatballs.

2. Materials and Methods

Liquid smoke was prepared from rice husk pyrolyzed at 300°C (T1), 350°C (T2), and 400°C (T3) in a pyrolysis reactor. The preparation followed the detailed procedures in the previous studies [27]. The conversion of rice husk-based liquid smoke into powdered liquid smoke was carried out using a spray dryer. To one liter of liquid smoke, maltodextrin, 30% of the volume was added and stirred. After thoroughly mixed, a spray dryer was used with a drying temperature of 170°C inlet and 70°C outlet for two hours and 2-bar pressure to produce a powder. The meat balls used as samples were prepared from 1 kg of cleaned chicken to which 300 grams of tapioca flour, egg, and spices such as pepper, shallots, beef seasoning, and salt were also added. The ingredients were mixed until a dough was formed. The dough was then made into meatballs and then boiled for about 20 minutes. The detail information on meat balls preparation can be found elsewhere [28]. Preservation was carried out by the sprinkling method. Having been coated with smoke powder thoroughly, each batch of the meatball samples was then tested for their TVB, TPC, and organoleptic properties every four hours. Detail procedures for TVB, TPC, and organoleptic analyses followed previous research [17]. The MPN tests were performed based on the Indonesian National Standard analysis for microbe contamination [29]. The analysis of the organoleptic test was carried out using statistical method (SPSS ver. 16) with one-way ANOVA and least significant difference (LSD).

3. Results and Discussion

3.1. Total Plate Count (TPC) Test. Total plate count test on meatball samples is one of the microbiological parameters to assess the material edibility and its rate of deterioration. The test results showed that the number of bacteria in the meatball samples ranged from 1.19×10^4 CFU/g to $>3 \times 10^5$ CFU/g. The value of $>3 \times 10^5$ CFU/g was started from 40 h storage time of control sample (without smoke powder), as can be seen in Figure 1.

The limit of TPC value in the meatballs based on the Indonesian National Standards (SNI) no. 02-2725-1992 [30] is 1×10^5 colonies/g. The total number of bacteria detected in the meatball samples for a period of 4 to 76 hours ranged from 1.19×10^4 CFU/g to 5.27×10^5 CFU/g. The pyrolysis temperature affected the characteristics of the smoke powder. As seen in Figure 1, the higher the pyrolysis temperature in the preparation of liquid smoke, the lower the number of bacterial colonies found. It was seen from the initial observation time to the end that the number of bacteria in the meatballs without smoke powder (T0) and in the samples with a lower pyrolysis temperature of liquid smoke (T1) had a higher TPC than that in the meatballs with T3 smoke powder.

In the first 24 hours of storage, the TPC of meatball in sample T0 was 7.03×10^4, while that of samples with T1, T2, and T3 smoke powder were lower, namely 2.91×10^4, 2.72×10^4, and 2.47×10^4, respectively. As shown in Figure 1, at 36 hours of storage at each pyrolysis temperature (300–400°C), the TPC did not reach 4×10^4 CFU/gram yet. The number of bacteria increased with the length of storage time at room temperature. Meanwhile, meatball sample T0 had exceeded the allowed threshold at a storage time of 36 hours, although the samples still lasted well up to 32 hours. In the meatball sample T1 until 72-hour observation time, the TPC value had exceeded the threshold (5.16×10^5 CFU/g), while in the meatball with smoke powder at the pyrolysis temperatures of 350°C (T2) and 400°C (T3), the TPC value had not exceeded the threshold. This is much better than the results in meatballs using liquid smoke, which only lasted up to 54 hours with a TPC value of 3.42×10^5 CFU/g [28]. The results showed that the pyrolysis temperature in the preparation of the smoke powder affected the growth of the bacteria in the meatballs. By 76-hour observation, the meatball samples were not suitable for consumption because the TPC value had passed the allowed limit. The best condition in this study was achieved by the sample with T3 smoke powder that, up to 72 hours of storage, still had a TPC value below the threshold.

3.2. Total Volatile Base (TVB) Test. One of the indicators to determine the damage to meatballs attributed to the enzyme and bacterial activity is the total volatile base (TVB). Figure 2 presents the results of the TVB analysis on the meatball samples. The TVB value is lower in samples with higher pyrolysis temperature in the preparation of the smoke powder. The maximum TVB value that is still suitable for consumption is 0.20 mgN/100 gr [31].

Figure 2 shows that the higher the pyrolysis temperature of the smoke powder preparation, the lower the TVB value. The TVB value did not increase significantly until 28 hours for meatballs coated with smoke powder, while in the control sample (T0), the TVB increased after 12 hours. The initial observations on the control sample as well as the samples coated with smoke powder T1, T2, and T3 showed that the TVB values ranged from 0.008 to 0.011 mgN/g. At 48 hours of storage, the meatball without the addition of smoke powder (T0) already had a TVB value exceeding the maximum threshold of 0.210 mgN/g, while the other samples had not reached 0.1 mgN/g yet.

During the 72 hours of observation, the meatballs still had good freshness and their TVB had not reached 0.20 mgN/g yet. By 72 hours of storage, meatballs coated with smoke powder prepared at 300 and 350°C pyrolysis temperatures have the TVB values exceeding the threshold, namely, 0.241 and 0.213 mgN/g. Meanwhile, meatballs

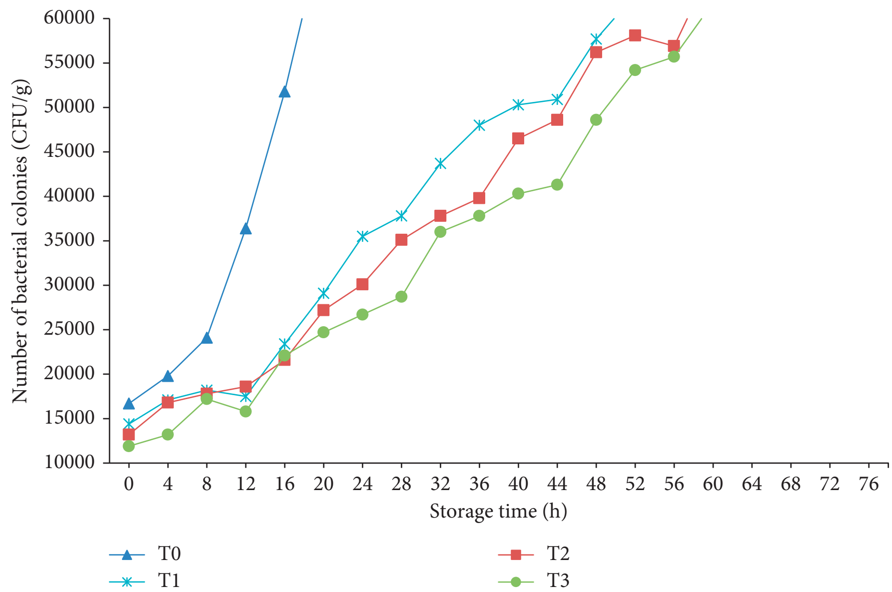


Figure 1: TPC test results on smoke powder-coated meatballs.

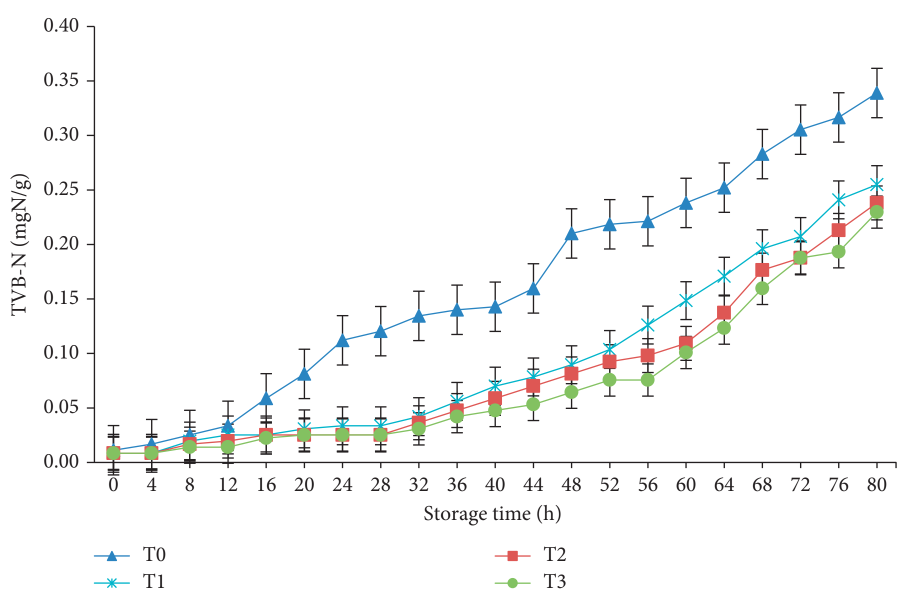


Figure 2: Effect of storage time on TVB on samples with T1–T3.

coated with smoke powder with a pyrolysis temperature of 400°C still had good freshness up to 72 hours. Previous studies showed that liquid smoke from durian husks could maintain the freshness of fish up to 60 hours with variations of liquid smoke concentration from 0.5 to 3% [17]. Meanwhile, the use of liquid smoke from palm kernel shells at 3% concentration as a meatball preservative could maintain the freshness up to 15 hours of immersion [32]. Another study by Ariestya et al. [33] using liquid smoke at 1.5% concentration to preserve tilapia meat showed that at 6 days of preservation, tilapia meat was still suitable for consumption with a TVB value of 24.267 mgN/g. The increase in TVB value is due to protein degradation that produces enzymes. These enzymes are produced from bacterial activity to break down proteins into amino acids and short peptide bonds producing several bases such as amines, ammonia, indole, and trimethylamine, which cause foul odor [34]. The longer the preservation, the more the bacterial activity will produce a base that causes spoilage, resulting in the increase of the TVB value [35].

3.3. Most Probable Number (MPN) Test of E. coli. The research results revealed that the total *E. coli* number in meatballs treated with smoke powder seemed to be lower than the number in meatballs not treated with smoke

Table 1: Test results for MPN *E. coli*.

Storage time (hr)	Liquid smoke powder	MPN/g	Description
0	T0	120	Q
	T1	0	Q
	T2	0	Q
	T3	0	Q
24	T0	1100	Q
	T1	0	Q
	T2	0	Q
	T3	0	Q
48	T0	>1100	NQ
	T1	43	Q
	T2	38	Q
	T3	23	Q
56	T1	160	Q
	T2	120	Q
	T3	120	Q
60	T1	290	Q
	T2	220	Q
	T3	150	Q
64	T1	460	Q
	T2	290	Q
	T3	240	Q
68	T1	1100	Q
	T2	1100	Q
	T3	1100	Q
72	T1	>1100	NQ
	T2	>1100	NQ
	T3	>1100	NQ

Q, qualified; NQ, not qualified.

powder (control). Smoke powder contained acid, carbonyl, and phenolics compound [23]. Phenolics disrupt bacteria's cytoplasmic membranes and contribute to antibacterial and antioxidant properties [36, 37].

According to the results presented in Table 1, the number of *E. coli* varied depending on the length of storage and the type of smoke powder sample used. At 40 h of preservation, the control had the highest number of *E. coli* (>1100 MPN/g), whereas the meatballs with smoke powder in samples T1, T2, and T3 reached a value of 1100 MPN/g at 68 hours. According to SNI [29], the meatballs are no longer suitable for consumption because they have exceeded the maximum permissible microbial contamination level of 1×10^5 MPN/g. These findings indicated that the application of smoke powder to the meatballs could inhibit the growth of *E. coli* for a period of up to 68 hours after the meatballs were prepared. After extended storage, the amount of coliform has increased to more than 1100 MPN/g.

3.4. Results of Organoleptic Tests

3.4.1. Aroma. Coating with smoke powder prepared at different pyrolysis temperatures affected the changes in the aroma of meatballs during storage. The results of the observations are presented in Table 2.

Observations on the meatball aroma as presented in Table 2 show that smoke powder with various pyrolysis temperatures had different effects on the aroma changes of the meatballs during storage time. Higher pyrolysis temperatures could slow down the development of odors in meatballs. The aroma of meatballs without smoke powder was still acceptable for 36 hours. The meatballs in sample T1 had an acceptable aroma during a storage time of 60 hours, while the aroma in samples T2 and T3 was still acceptable during a storage time of 72 hours. After 76 hours of storage, the meatballs began to emit an unpleasant aroma. Based on the results of the LSD test, the differences in pyrolysis temperature during the preparation of liquid smoke affected the aroma of the meatballs during the storage.

3.4.2. Texture. Texture testing was carried out by examining the meatballs texture by hand. The results of texture observations in Table 3 show that the best meatball texture was represented in sample T3, whose meat texture was still firm during 72 hours of storage. Meanwhile, at 72 hours of storage, both samples T1 and T2 started to soften, i.e., changed from a bit firm to soft. During storage time, the texture values decreased, which was similar with earlier research [38]. Meatballs without smoke powder (T0) could only last well for 36 hours.

The average texture of the meatballs began to change after 48 hours of storage. The decrease in the meatball texture indicates the growth of microorganisms during storage [39]. The rotting of the meatballs is indicated by

Table 2: The aroma of meatballs coated with smoke powder of various pyrolysis temperatures.

Sample	0 h	12 h	24 h	36 h	48 h	60 h	68 h	72 h	76 h	80 h
T0	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$4, 9 \pm 0, 2^{A}$	$3, 9 \pm 0, 3^{A}$	$2, 3 \pm 0, 3^{A}$	$1, 6 \pm 0, 0^{A}$	$1, 3 \pm 0, 3^{A}$	$1 \pm 0, 0^{A}$	$1 \pm 0, 0^{A}$	$1 \pm 0, 0^{A}$
T1	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{B}$	$4, 1 \pm 0, 2^{B}$	$3, 4 \pm 0, 5^{B}$	$2, 5 \pm 0, 5^{B}$	$2 \pm 0, 0^{B}$	$1, 6 \pm 0, 54^{A}$	$1 \pm 0, 0^{A}$
T2	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{B}$	$4, 3 \pm 0, 6^{B}$	$3, 5 \pm 0, 8^{B}$	$3 \pm 0, 0^{C}$	$3 \pm 0, 15^{C}$	$2 \pm 0, 04^{B}$	$1 \pm 0, 0^{A}$
T3	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{B}$	$5 \pm 0, 0^{C}$	$4, 2 \pm 0, 4^{C}$	$3, 4 \pm 0, 4^{C}$	$3 \pm 0, 06^{C}$	$2 \pm 0, 05^{B}$	1.2 ± 0.15^{A}

1, very smelly; 2, smelly; 3, fairly smelly; 4, quite smelly; 5, not smelly. The different superscript letters in the columns represent the actual differences with $\alpha = 0.05$.

Table 3: The texture of meatballs coated with smoke powder of various pyrolysis temperatures.

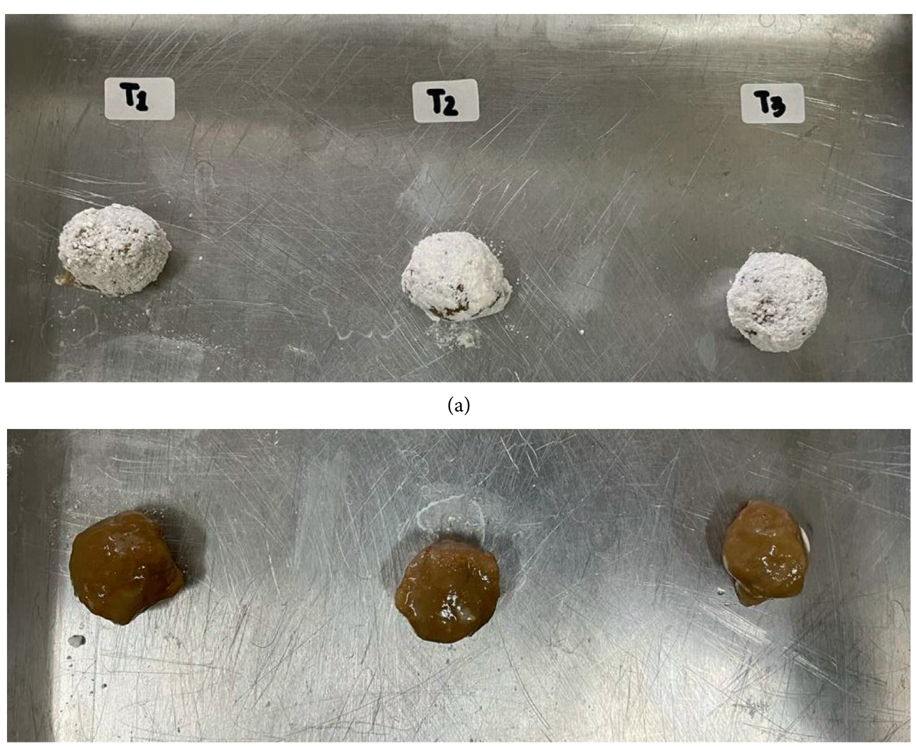
Sample	0 h	12 h	24 h	36 h	48 h	60 h	68 h	72 h	76 h	80 h
T0	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$2.8 \pm 0, 6^{A}$	$2.1 \pm 0, 2^{A}$	$1.5 \pm 0, 5^{A}$	$1.1 \pm 0, 0^{A}$	$1 \pm 0, 0^{A}$	$1 \pm 0, 0^{A}$
T1	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$4.0 \pm 0, 0^{B}$	$3.7 \pm 0, 6^{B}$	$3 \pm 1, 0^{B}$	$2.3 \pm 0, 5^{B}$	$1.4 \pm 0, 5^{A}$	$1.2 \pm 0, 3^{A}$
T2	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$4.1 \pm 0, 0^{B}$	$3.6 \pm 0, 5^{B}$	$3.3 \pm 0, 6^{B}$	$3 \pm 0, 1^{C}$	$2.5 \pm 0, 5^{B}$	$1.6 \pm 0, 5^{A}$
T3	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$4.7 \pm 0, 5^{B}$	$4.1 \pm 0, 2^{C}$	$3.6 \pm 0, 5^{B}$	$3.3 \pm 0, 5^{C}$	$2.6 \pm 0, 6^{B}$	$2 \pm 0, 0^{B}$

1, squishy; 2, soft; 3, a bit firm; 4, quite firm 5, firm. The different superscript letters in the columns represent the actual differences with $\alpha = 0.05$.

Table 4: The color of meatballs coated with smoke powder of various pyrolysis temperatures.

Sample	0 h	12 h	24 h	36 h	48 h	60 h	68 h	72 h	76 h	80 h
T0	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$2, 3 \pm 0, 6^{A}$	$1, 8 \pm 0, 3^{A}$	$1, 8 \pm 0, 4^{A}$	$1, 8 \pm 0, 3^{A}$	$1, 7 \pm 0, 2^{A}$
T1	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$3, 7 \pm 0, 6^{B}$	$3 \pm 1, 0^{B}$	$2, 3 \pm 0, 6^{B}$	$2 \pm 0, 0^{B}$	$1, 9 \pm 0, 1^{A}$
T2	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$3, 7 \pm 0, 6^{B}$	$3, 7 \pm 0, 6^{B}$	$3 \pm 0, 0^{C}$	$2 \pm 0, 0^{B}$	$2 \pm 0, 0^{B}$
T3	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$5 \pm 0, 0^{A}$	$4 \pm 0, 1^{C}$	$4 \pm 0, 0^{C}$	$3, 6 \pm 0, 6^{C}$	$3 \pm 0, 0^{C}$	$2, 3 \pm 0, 6^{B}$

1, white; 2, greyish white; 3, pale grey; 4, grey; 5, dark grey. The different superscript letters in the columns represent the actual differences with $\alpha = 0.05$.



(a)

(b)

Figure 3: Continued.

(c)

Figure 3: The condition of tested samples at various storage times ((a) 0 h, (b) 24 h, and (c) 72 h).

the smaller value of the texture observations. Rotting can also be described as the breakdown of meatballs by microorganisms that destroy the structure into a very soft and watery product [40]. From the results of the LSD test, it was found that the differences in the pyrolysis temperature during the preparation of liquid smoke had a significant difference in the texture of the preserved meatballs.

3.4.3. Color. The results of color observations in Table 4 show that smoke powder affected the differences in the color change of meatballs at each storage time. The results of color observations for samples with smoke powder prepared at various pyrolysis temperatures showed the same color at 0 to 36 hours of storage. The treated sample had a darker color than the control did. Table 4 shows that the best lasting color is shown by the meatball sample coated with smoke powder prepared at a pyrolysis temperature of 400°C (T3), where the grey color of the meatballs could last for 76 hours. At 80 hours, the meatball color had changed. The change of color with increasing storage time can be seen in Figure 3. The color change was caused by oxidizing compounds (such as peroxides) or the presence of H_2S that the bacteria produced. The one-way ANOVA test showed a significant difference ($\alpha = 0.05$) for each treatment, while the LSD test also showed significantly different results.

4. Conclusions

Smoke powder prepared from pyrolyzed rice husks has the potential as an alternative preservative for meatballs. The results showed that the TPC and TVB values were within the permissible limits up to 72 hours of storage, with the TPC and TVB values being 6.87 × 104 CFU/g and 0.18 mgN/g, respectively. The LSD test showed that the differences in pyrolysis temperature during the preparation of liquid smoke before being converted to smoke powder affected the characteristics of the smoke powder, which in turn affected the aroma, texture, and color of the preserved meatballs. The results of the organoleptic test and MPN test showed that the smoke powder-coated meatballs could last up to 72 hours.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare no conflicts of interest.

Acknowledgments

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