



Investigation of Microbial and Physicochemical Quality of Hamsiköy Rice Pudding: A Comparative Study on Baked and Non-Baked Samples

Gülsüm Ordu^{1,a}, Fırat Yılmaz^{2,b,*}

¹Gümüşhane University, Faculty of Engineering and Natural Sciences, Department of Food Engineering, 29100, Gümüşhane, Türkiye.

*Corresponding author

ARTICLE INFO

Research Article

Received : 30.08.2025

Accepted : 16.04.2025

Keywords:

Rice pudding

Hydroxymethylfurfural (HMF)

Physicochemical properties

Microbiological quality

Milk-based dessert

ABSTRACT

The study examines the microbial and physicochemical properties of Hamsiköy rice pudding, comparing non-baked and baked samples. Microbiological analyses revealed notably higher counts of total aerobic mesophilic bacteria (TAMB), psychophilic bacteria, and lactic acid bacteria (LAB) in non-baked samples, with TAMB and LAB reaching 5.69 log cfu/g and 6.06 log cfu/g, respectively. Conversely, the baking process led to a decline in microbial load, as evidenced by the lower counts observed in the baked samples. Additionally, chemical analyses revealed that the baked samples exhibited higher dry matter, fat, and protein content compared to the non-baked samples. Additionally, the cooked rice pudding samples had lower L^* values, indicating a darker colour. Despite some variations, the chemical properties observed in this study are generally consistent with those reported in previous studies. The study concludes that the baking process enhances the microbiological and physicochemical quality of Hamsiköy rice pudding, thus making it a product with enhanced safety and quality. Hydroxymethylfurfural (HMF), an indicator of heat treatment, was analyzed as well and was found to be higher in baked samples. Colour parameters (L^* , a^* , b^*) revealed darker appearance in baked samples, aligning with consumer expectations for traditional Hamsiköy rice pudding.

^a Gulsumordu0@gmail.com

^{ID} <https://orcid.org/0000-0002-1974-4304>

^b asst.prof.firatyilmaz@gmail.com

^{ID} <https://orcid.org/0000-0003-3633-0012>



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Introduction

Milk and dairy products are important sources of essential nutrients, particularly proteins, calcium, and vitamins (Bilgin et al., 2005). While their general nutritional role is widely recognized, this study specifically focuses on Hamsiköy rice pudding, a traditional Turkish rice pudding. The main objective is to investigate the microbiological and physicochemical differences between baked and non-baked forms, with an emphasis on food safety.

The processing of dairy products such as milk, butter, cheese, and yoghurt provides two primary benefits: it extends shelf life and enables the production of dairy-based desserts (Yerlikaya and Kınık, 2019). These desserts are often considered more nutritious due to their relatively low fat, sugar, and flour content, while still offering essential nutrients such as protein, vitamins, and minerals. They are particularly beneficial for high-risk groups, including children, pregnant women, and breastfeeding mothers (Kadağan, 2015; Kadağan & Arslan, 2021).

Among milk-based desserts, rice pudding is the most well-known and widely consumed. A similar dessert called

“Uwa” is referenced in the Divan-ü Lügatit-Türk, with the preparation method described as follows: “After the rice is cooked, it is placed in cold water; then the water is drained, sugar is added, and it is eaten cold” (Arıkan, 2016).

Although rice pudding is not a rich source of vitamins and minerals, it does offer modest amounts of calcium and phosphorus, making it a healthy addition to the diet when consumed in moderation (Yeşilyurt, 2020). However, caution must be exercised regarding added sugars, as excessive consumption of processed foods and sugary beverages is associated with various health issues, including dental caries, obesity, hypertension, diabetes, and metabolic syndrome (Köylü, 2019). The American Heart Association recommends a daily limit of 100 calories from added sugars for women and 150 calories for men (Yeşilyurt, 2020).

Within the diverse landscape of Turkish cuisine, rice pudding stands out as a popular dessert, showcasing regional culinary variations. The baked version of rice pudding, in particular, exhibits unique sensory characteristics (Köylü, 2019). A notable example is

Hamsiköy Sütlacı, a specialty from the Hamsiköy district in the Black Sea region of Turkey, which has earned a significant place in Turkish culinary heritage (Tomaç et al., 2014).

The traditional recipe for Hamsiköy rice pudding includes 1 liter of raw cow's milk, 60 grams of rice, 70 grams of sugar, and half a teaspoon of salt. These proportions are consistently maintained across its various preparations. The milk used is obtained from cows fed on a diverse flora unique to the climatic conditions of Hamsiköy, Çıralı, Güzelyayla, Dikkaya, and Başar villages at the base of Zigana Mountain, contributing to its distinctive flavor profile. Two preparation methods are commonly employed: one involves cooking the rice, milk, and sugar mixture for a fresh version of rice pudding, while the other involves baking the mixture to form a caramelized top layer, which improves both texture and shelf life (Anonymous, 2017).

This study aims to examine the microbiological and chemical properties of Hamsiköy rice pudding, which is commonly consumed across Turkey. Samples prepared in both baked and non-baked forms were collected from markets in the Trabzon province.

Material and Methods

In this study, 40 Hamsiköy rice puddings (20 baked rice pudding + 20 non-baked rice pudding) were procured from various producers and vendors at the Trabzon market and then transported to the Food Technology Department laboratory at Gümüşhane University. The samples were stored at a temperature of +4°C until analysis.

Microbiological Analysis

In the analysis of microbiological samples, 10 g of each sample was weighed and placed in sterile stomacher bags. Thereafter, 90 ml of sterile physiological saline was added, and the mixture was homogenised for 2 minutes. A 1 ml portion of the homogenate was then subjected to further dilution (1:10) and transferred to a test tube containing physiological saline. This process was repeated to create dilution series up to 10^{-5} (Yılmaz et al., 2025). The total aerobic mesophilic bacteria (TAMB) counts were carried out following the methodology outlined by Ataman (2020), while the total aerobic psychrophilic bacteria (TAPB) and *Enterobacteriaceae* counts were performed following the protocols established by Diler et al. (2018). Both MRS and M17 media were employed for lactic acid bacteria (LAB) enumeration to ensure a broader detection range of mesophilic and thermophilic LAB strains, ensuring greater accuracy. LAB on MRS agar, yeast-mould and coliform bacteria counts were executed following the methods detailed by Helvacioğlu (2020). LAB counts on M17 agar were performed according to Yılmaz et al. (2025). *Staphylococcus aureus* counts were performed according to Yılmaz & Dagdemir (2012). *Pseudomonas spp.* counts were performed according to Ceylan & Demirkaya (2011).

Physicochemical Analysis

The differences in physicochemical properties, such as higher protein and ash in baked samples, are likely due to concentration effects from water evaporation during baking. The higher HMF levels confirm thermal impact,

while differences in lactose and sucrose reflect Maillard reactions and caramelization effects, which influence both flavour and colour. The AOAC (2012) method was used to determine the physico-chemical (total solid, titrable acidity, fat, protein, ash, pH) properties of rice pudding samples. The colour measurement was conducted using the CR400 instrument (KonicaMinolta, Inc., Osaka, Japan) (Şengül et al., 2018). The sucrose, lactose and hydroxymethylfurfural (HMF) contents of rice pudding samples were quantified in accordance to Bogdanov et al. (2002). Sucrose and lactose contents were determined by dissolving molasses samples in deionised water and analysing them by high-performance liquid chromatography (HPLC) (Shimadzu, Japan). The results were calculated using the mobile phase, which was a mixture of acetonitrile and water. For the measurement of HMF, the molasses sample was dissolved in deionised water and analysed by HPLC. The amounts of HMF (hydroxymethylfurfural) present in the samples were quantified using an HPLC device with a C-18 column. The chromatograms were obtained at a 284 nm wavelength using a Diode Array Detector (Shimadzu, Japan). The amount of HMF was determined using an external calibration curve.

Statistical Analyses

The statistical data were analysed using SPSS 22.0 (SPSS Inc., Chicago, USA). Normality of the data was checked using the One-way ANOVA was performed to evaluate differences between groups, and Tukey's HSD post-hoc test was applied where appropriate ($p < 0.05$).

Result and Discussion

Microbiological Counts

Importantly, the microbial counts were evaluated against food safety criteria. Although some non-baked samples revealed elevated coliform and *Pseudomonas spp.* counts, they remained within internationally accepted safety thresholds. However, the higher values still indicate potential hygiene shortcomings during production and handling. Differences observed between baked and non-baked samples may be attributed to reduced water activity, protein denaturation, and lower pH stability in baked products, which collectively inhibit microbial growth.

A comprehensive investigation was conducted into the presence of various microorganisms in Hamsiköy rice pudding samples (Table 1 and Table 2). The investigation encompassed total aerobic mesophilic bacteria (TAMB), yeast-moulds, total aerobic psychrophilic bacteria (TAPB), lactic acid bacteria (LAB), and pathogenic bacteria. The analysis revealed that TAMB, TAPB and LAB counts exhibited a marked increase in non-baked rice pudding samples compared to baked samples. Notably, TAMB counts attained the highest values of 5.69 log cfu/g, while LAB counts peaked at 6.06 log cfu/g in the non-baked rice pudding samples. Conversely, these values were at their lowest in the baked samples, with 1.99 log cfu/g and 1.99 log cfu/g recorded, respectively. These findings indicate higher microbial counts than the results obtained in previous studies (Alişarlı, et al., 2002; Arıkan, 2016; Öksüztepe et al., 2013).

Table 1. The microbiological counts of Hamsiköy rice pudding samples

Sample	TAMB (log cfu/g)		TAPB (log cfu/g)		LAB on MRS agar (log cfu/g)		LAB on M17 agar (log cfu/g)		Yeast-Mould (log cfu/g)	
	BRP	NBRP	BRP	NBRP	BRP	NBRP	BRP	NBRP	BRP	NBRP
1	2.09±0.18	5.69±0.02	4.27±0.01	5.60±0.04	3.69±0.33	5.60±0.12	4.30±0.01	5.54±0.01	3.86±0.05	8.87±1.89
2	2.26±0.46	4.90±0.00	2.95±0.05	4.01±0.72	1.99±0.00	4.34±0.18	2.80±0.28	4.28±0.03	1.99±0.00	2.65±0.31
3	4.15±0.08	4.18±0.09	4.60±0.11	4.31±0.15	3.27±0.01	1.50±0.17	3.55±0.62	4.35±0.06	2.86±0.06	2.63±0.55
4	3.85±0.18	4.56±0.26	4.09±0.05	3.61±0.54	1.99±0.00	4.23±0.21	3.46±0.02	3.84±0.00	2.07±0.14	2.48±0.46
5	4.88±0.11	5.16±0.18	4.28±0.01	4.42±0.16	4.09±0.06	4.87±0.17	3.04±0.02	4.70±0.00	4.94±0.10	2.80±0.17
6	2.42±0.33	4.16±0.27	3.13±0.06	4.62±0.02	2.50±0.09	3.89±0.25	3.14±0.00	5.43±0.09	3.02±0.30	3.42±0.31
7	2.65±0.07	5.00±0.09	3.13±0.08	4.74±0.46	2.38±0.00	5.04±0.16	2.53±0.02	5.03±0.03	3.15±0.04	3.20±0.17
8	5.15±0.02	3.30±0.00	5.08±0.11	5.26±0.32	5.48±0.01	3.30±0.30	5.35±0.02	5.11±0.01	3.58±0.09	4.31±0.27
9	3.69±0.78	4.90±0.37	4.09±0.08	5.48±0.09	2.78±0.51	4.39±0.08	3.20±0.24	4.15±0.40	3.43±0.00	3.61±0.27
10	3.81±0.05	5.10±0.29	3.40±0.00	4.61±0.27	1.99±0.00	5.33±0.14	2.89±0.26	4.00±0.00	3.26±0.01	3.69±0.54
11	3.26±0.08	5.60±0.05	3.55±0.03	5.56±0.12	3.21±0.03	2.29±0.17	3.25±0.09	5.82±0.01	2.40±0.10	2.77±0.00
12	3.93±0.34	4.10±0.10	4.44±0.00	5.26±0.13	3.35±0.09	3.73±0.14	3.77±0.04	4.50±0.03	3.64±0.12	4.00±0.40
13	4.23±0.01	4.15±0.05	4.69±0.46	5.26±0.05	1.99±0.00	5.66±0.05	3.40±0.01	4.57±0.06	4.11±0.26	3.30±0.00
14	5.56±0.01	4.46±0.27	4.97±0.08	4.84±0.64	5.16±0.02	3.00±0.31	4.92±0.04	4.03±0.00	4.03±0.08	2.47±0.00
15	3.19±0.28	4.05±0.05	3.50±0.00	5.10±0.13	3.28±0.00	5.94±0.06	3.27±0.23	4.94±0.00	3.25±0.01	2.30±0.00
16	5.82±0.04	4.13±0.13	5.47±0.02	4.54±0.13	3.00±0.46	5.97±0.02	5.58±0.06	5.71±0.10	3.44±0.22	3.28±0.03
17	5.15±0.43	4.05±0.05	5.17±0.06	2.60±0.00	1.99±0.00	4.44±0.29	4.64±0.21	5.28±0.03	1.99±0.00	2.56±0.08
18	4.66±0.98	4.09±0.08	4.91±0.06	5.06±0.02	1.99±0.00	4.81±0.15	1.99±0.00	5.36±0.01	2.53±0.40	2.93±0.06
19	1.99±0.00	4.05±0.09	2.32±0.58	4.47±0.40	1.99±0.00	3.48±0.20	4.25±0.61	4.36±0.42	1.99±0.00	3.18±0.25
20	3.36±0.29	2.08±0.68	4.86±0.15	5.07±0.20	1.99±0.00	6.06±0.08	2.96±0.31	4.13±0.12	4.40±0.25	1.83±0.12
Means	3.81±0.15	4.37±0.11	4.15±0.86	4.72±0.75	2.95±0.11	4.39±0.16	3.61±0.95	4.75±0.62	3.20±0.10	2.98±0.66

BRP: Baked rice pudding, NBRP: Non-baked rice pudding

Table 2. The microbiological counts of Hamsiköy rice puddings

Sample	Coliform (log cfu/g)		Enterobacteriaceae (log cfu/g)		Staphylococcus aureus (log cfu/g)		Pseudomonas spp. (log cfu/g)	
	BRP	NBRP	BRP	NBRP	BRP	NBRP	BRP	NBRP
1	1.84±0.61	0.90±0.00	1.83±0.49	0.90±0.00	2.49±0.00	4.69±0.33	0.99±0.00	3.59±0.37
2	0.99±0.00	3.10±0.00	1.49±0.00	0.90±0.00	1.99±0.00	4.43±0.06	0.99±0.00	1.09±0.33
3	2.65±0.01	0.90±0.00	2.98±0.20	0.90±0.00	3.31±0.14	2.25±0.04	3.85±0.30	1.43±0.46
4	1.41±0.25	3.23±0.10	1.49±0.00	3.29±0.21	3.07±0.11	2.27±0.04	0.99±0.00	1.03±0.23
5	1.67±0.25	3.86±0.03	1.71±0.29	3.72±0.04	2.81±0.07	4.02±0.04	5.09±0.39	3.93±0.08
6	2.72±0.25	3.10±0.00	3.13±0.26	4.92±0.09	3.31±0.14	4.61±0.33	0.99±0.00	4.01±0.02
7	2.10±0.03	1.60±0.00	3.35±0.01	1.30±0.00	1.99±0.00	4.17±0.05	0.99±0.00	3.91±0.27
8	2.10±0.28	3.10±0.00	2.81±0.01	4.98±0.01	2.99±0.03	3.40±0.35	0.99±0.00	4.25±0.19
9	1.96±0.06	3.20±0.12	2.59±0.34	4.04±0.06	2.30±0.12	3.81±0.21	0.99±0.00	3.50±0.10
10	2.30±0.06	3.10±0.00	3.37±0.34	3.00±0.00	2.61±0.24	3.97±0.12	0.99±0.00	3.16±0.15
11	1.36 ± 0.12	4.03±0.06	1.49±0.00	4.55±0.07	3.16±0.06	3.00±0.00	0.99±0.00	2.85±0.33
12	0.99±0.00	4.59±0.08	2.23±0.32	4.49±0.16	2.09±0.09	2.69±0.60	0.99±0.00	3.70±0.17
13	1.58±0.05	4.10±0.10	1.61±0.20	3.10±0.00	3.12±0.11	3.34±0.04	0.99±0.00	1.47±0.00
14	1.91±0.05	3.74±0.06	1.54±0.09	3.55±0.17	3.11±0.11	2.55±0.25	0.99±0.00	3.08±0.08
15	2.33±0.02	4.10±0.10	2.23±0.05	6.02±0.08	2.09±0.18	3.14±0.15	0.99±0.00	3.77±0.12
16	0.99±0.00	4.10±0.10	0.99±0.00	4.62±0.24	1.99±0.00	0.90±0.00	0.99±0.00	4.20±0.17
17	0.99±0.00	3.16±0.17	3.52±0.09	2.08±0.13	2.66±1.16	2.62±0.13	0.99±0.00	1.75±0.09
18	5.37±0.09	4.88±0.03	5.18±0.02	4.67±0.36	4.13±0.20	2.16±0.03	0.99±0.00	3.87±0.15
19	0.99±0.00	4.10±0.10	0.99±0.00	5.08±0.07	3.27±0.63	3.02±0.48	0.99±0.00	3.85±0.15
20	2.46±0.09	4.50±0.10	3.10±0.09	4.74±0.63	1.99±0.00	3.17±0.29	0.99±0.00	3.21±0.19
Means	1.92±0.12	3.36±0.14	2.38±0.13	3.54±0.21	2.72±0.08	3.21±0.96	1.34±0.75	3.08±0.14

BRP: Baked rice pudding, NBRP: Non-baked rice pudding

In the microbiological analyses of Hamsiköy rice pudding samples, coliform bacteria, *Enterobacteriaceae*, *S. aureus*, *Pseudomonas* spp. and mould and yeast counts were analyzed. The coliform bacteria count reached its highest value of 4.88 log cfu/g in the non-baked rice pudding samples, while the lowest value of 0.99 log cfu/g was recorded in the baked samples. On average, coliform bacteria counts were higher in non-baked rice pudding

samples (3.36 log cfu/g). A similar trend was observed for *Enterobacteriaceae* and *S. aureus* counts, which were also higher in the same samples.

In other study (Öksüztepe et al., 2013), *S. aureus* could not be detected in rice pudding samples, while the number of *S. aureus* detected in other study (Şahiner, 2019) was lower than that detected in this study. *Pseudomonas* spp. counts were found to be highest in non-baked samples

(5.09 log cfu/g) and lowest in baked samples < 1.00 log cfu/g. However, *Pseudomonas* were detected in higher numbers in non-baked rice pudding samples. In the study conducted by (Arıkan, 2016), lower levels of *Pseudomonas* were detected in rice pudding samples.

In rice pudding samples, the highest yeast-moulds count was determined as 8.87 in the non-baked rice pudding sample. However, it was observed that the baked rice pudding samples exhibited higher mean yeast-moulds counts. Compared to the findings of previous studies (Alişarlı et al., 2002; Arıkan, 2016; Öksüztepe et al., 2013), the yeast-moulds numbers detected in this study were found to be higher.

The baking process has been demonstrated to notably reduce microbial load; however, it has been observed to exert a particularly marked effect on coliform, *Enterobacteriaceae* and *Pseudomonas spp.* counts. In summary, with the exception of yeast and mould counts, the levels of other microbiological properties were found to be notably elevated in samples of non-baked rice pudding (Figure 1).

The microbiological analyses conducted reveal that the vast majority of the examined rice pudding samples (baked and non-baked) are generally compliant with the limit values specified in the Turkish Food Codex Microbiological Criteria Regulation. The mean total aerobic mesophilic bacteria (TAMB) count was 3.81 log cfu/g, which is below the upper limit of 5.00 log cfu/g specified in the regulation for heat-treated milk-based desserts. However, coliform bacteria and *Enterobacteriaceae* levels exceeded 3.00 log cfu/g in some samples, indicating limited non-compliance in these parameters, which are considered indicators of hygiene. Furthermore, *Staphylococcus aureus* contamination was detected at levels above 3.00 log cfu/g in certain samples, suggesting the possibility of cross-contamination or inadequate staff hygiene practices. Furthermore, yeast and mould counts in some baked rice pudding samples exceeded 4.00 log cfu/g, indicating values that were outside the acceptable range in terms of quality. These results indicate that the overall microbiological quality of the products is acceptable, but some samples show non-

compliance with certain criteria of the Turkish Food Codex (Anonymous, 2011). This highlights the need for more careful management of critical points in the production process, such as hygiene and thermal processing control.

Physicochemical Analysis

The differences in physicochemical properties, such as higher protein and ash in baked samples, are likely due to concentration effects from water evaporation during baking. The higher HMF levels confirm thermal impact, while differences in lactose and sucrose reflect Maillard reactions and caramelization effects, which influence both flavour and colour.

Table 3 shows the results of the chemical analysis of the Hamsiköy rice pudding samples. Statistical evaluation of the average values of the physicochemical properties of Hamsiköy rice puddings is given in Figure 2, Figure 3 and Figure 4. It was determined that total solids values were high in cooked rice pudding samples, and similarly, the average dry matter value was notably higher in cooked rice pudding. Subsequent to the evaluations, it was ascertained that the mean dry matter, fat, protein, titratable acidity, pH and ash levels of the baked Hamsiköy rice pudding samples were elevated. However, a statistically significant difference was observed in the average pH values of the two rice pudding samples (Figure 3). The total solid values determined in studies such as Kadağan (2015), Kadağan & Arslan (2021) and Seçim & Uçar (2014) are at lower levels compared to the findings of this study. A similar trend was observed for fat, protein, pH, ash and other components.

The fat content of the baked rice pudding was found to be higher, but lower values were reported in studies such as Degirmenci & Erkurt (2020), Seçim & Uçar (2014) and Kadağan & Arslan (2021). The protein ratio was found to be higher in the baked samples, and the protein values determined in previous studies (Deshmukh et al., 2020; Jose et al., 2022) were in parallel with these findings. However, in this study of protein values were be highest according to Degirmenci & Erkurt (2020). Titratable acidity and pH values remained at similar levels in both samples, while ash content was higher in baked samples.

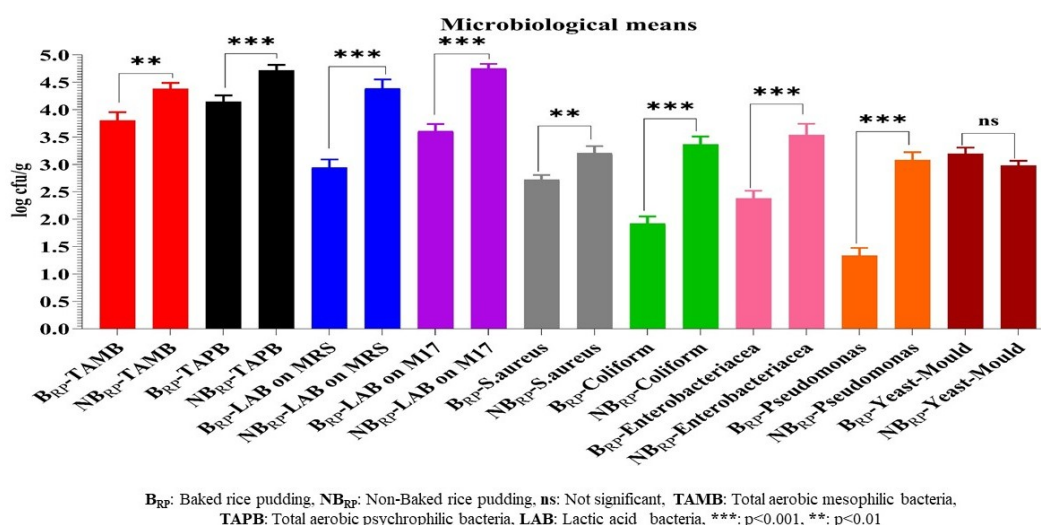


Figure 1. The microbiological counts mean of Hamsiköy rice pudding samples

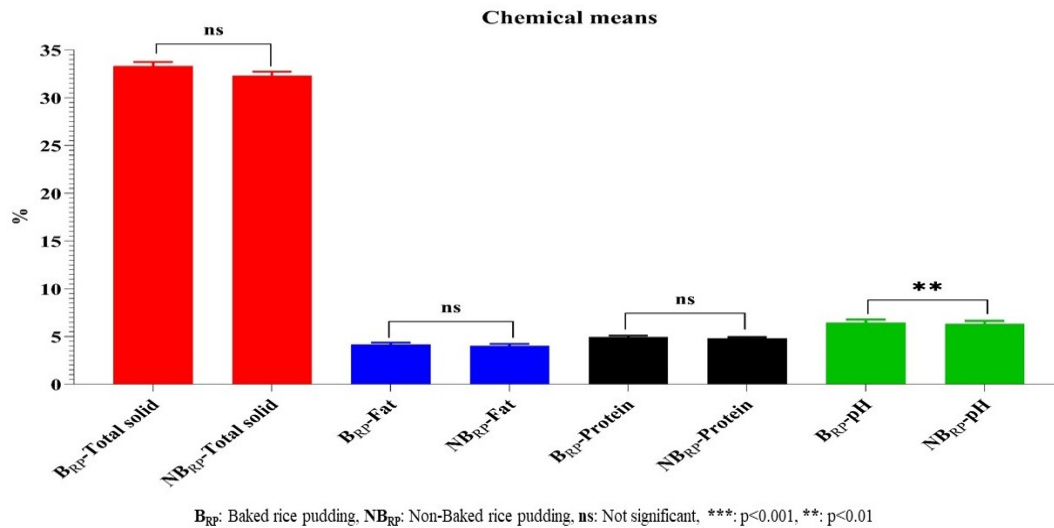


Figure 2. The means of physicochemical properties in Hamsiköy rice pudding samples

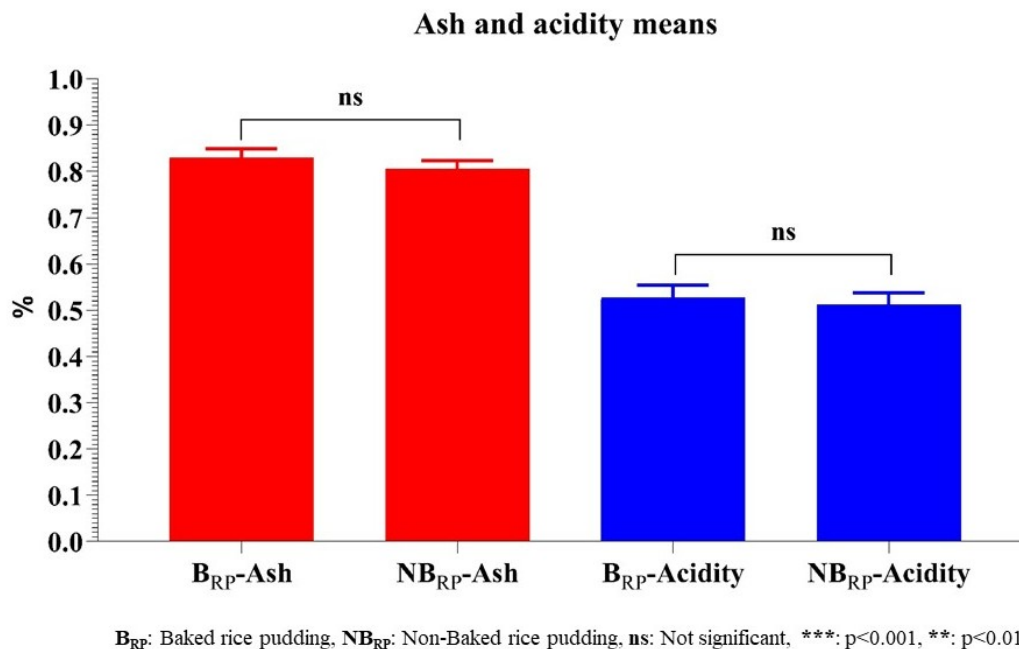


Figure 3. The means of pH levels of Hamsiköy rice pudding samples

In the study conducted by Arıkan (2016), the titratable acidity rate of rice pudding samples was found to be similar to the results obtained in the present study. Conversely, the titratable acidity levels determined in previous studies (Aytaç 2017; Jose et al., 2022; Ozcan et al., 2010) were found to be lower than those reported in the present study. In the research carried out by Arıkan (2016), Aytaç (2017), Ersöz (2019), Köylü (2019), Yeşilyurt (2020) and Ozcan et al. (2010), it was established that the pH values of rice pudding and milk dessert samples were analogous to the findings of the present study. However, a contrary finding was reported in the study conducted by Seçim & Uçar (2014), who found that the pH values of rice pudding samples sold in the market were higher than the results obtained in this study.

The investigation revealed that the mean ash content of the samples was lower, though the variation observed was not deemed to be statistically significant. Following a

thorough analysis, it was determined that the ash values of the rice pudding samples were comparable to the ash values established by Köylü (2019) and Arıkan (2016). The study conducted by Jose et al. (2022), Seçim & Uçar (2014) determined the amount of ash to be at a lower level than that which was found in the present research.

The higher protein, fat and ash content in baked rice pudding samples compared to non-baked samples is due to water loss during the baking process. Consequently, the moisture content of the product is reduced, resulting in an increase in dry matter content. Consequently, components other than water, namely protein, fat and minerals, become more concentrated and are measured at higher levels in analyses. This assertion is further substantiated by the elevated total solid matter content observed in baked products (Naik et al. 2023).

The HMF, sucrose and lactose amounts of Hamsiköy rice pudding samples are given in Table 4.

Table 3. The physicochemical properties of Hamsiköy rice pudding samples

S	Total solid (%)		Fat (%)		Protein (%)	
	BRP	NBRP	BRP	NBRP	BRP	NBRP
1	32.93±0.51	31.95±0.28	3.67±0.31	3.56±0.17	4.12±0.44	4.00±0.25
2	39.29±0.35	38.11±0.20	3.13±0.12	3.04±0.06	3.44±0.18	3.34±0.10
3	35.39±0.18	34.33±0.10	3.47±0.12	3.36±0.06	4.35±0.26	4.22±0.14
4	35.66±0.18	34.59±0.10	4.13±0.12	4.01±0.06	4.79±0.19	4.65±0.11
5	29.81±0.16	28.92±0.09	2.67±0.12	2.59±0.06	5.14±0.51	4.99±0.28
6	32.89±0.15	31.91±0.08	2.67±0.12	2.59±0.06	4.65±0.27	4.51±0.15
7	34.67±0.09	33.63±0.05	6.13±0.12	5.95±0.06	5.75±0.21	5.57±0.11
8	34.40±0.32	33.37±0.18	4.87±0.12	4.72±0.06	6.69±0.21	6.49±0.12
9	37.41±0.04	36.29±0.02	7.07±0.12	6.85±0.06	6.38±0.17	6.19±0.09
10	34.04±0.27	33.02±0.15	2.27±0.12	2.20±0.06	4.67±0.19	4.53±0.11
11	39.78±0.03	38.59±0.02	7.73±0.12	7.50±0.06	7.30±0.31	7.08±0.18
12	34.73±0.05	33.69±0.03	5.07±0.12	4.91±0.06	5.90±0.35	5.72±0.19
13	32.45±0.24	31.48±0.14	4.13±0.12	4.01±0.06	5.48±0.18	5.32±0.10
14	28.36±0.14	27.50±0.08	2.87±0.12	2.78±0.06	4.22±0.19	4.09±0.11
15	31.46±0.05	30.52±0.03	3.00±0.20	2.91±0.11	4.47±0.15	4.34±0.08
16	29.06±0.51	28.19±0.28	3.47±0.12	3.36±0.06	3.30±0.47	3.20±0.26
17	35.23±0.04	34.18±0.02	5.67±0.12	5.50±0.06	4.63±0.11	4.49±0.06
18	29.13±0.05	28.26±0.03	3.73±0.23	3.62±0.13	4.33±0.22	4.20±0.12
19	29.68±0.11	28.79±0.06	4.07±0.12	3.94±0.06	4.91±0.30	4.76±0.17
20	29.87±0.15	28.98±0.08	3.47±0.12	3.36±0.06	4.54±0.26	4.40±0.14
M	33.31±0.43	32.31±0.42	4.16±0.19	4.04±0.19	4.95±0.13	4.80±0.13
S	Titrable acidity (% Lactic acid)		pH		Ash (%)	
	BRP	NBRP	BRP	NBRP	BRP	NBRP
1	0.57±0.01	0.55±0.01	6.50±0.02	6.37±0.02	0.68±0.02	0.66±0.01
2	0.41±0.02	0.40±0.01	6.64±0.01	6.51±0.01	0.47±0.03	0.46±0.02
3	0.55±0.01	0.54±0.01	6.42±0.01	6.29±0.01	0.79±0.01	0.77±0.01
4	0.61±0.01	0.59±0.01	6.44±0.01	6.31±0.01	0.77±0.02	0.74±0.01
5	0.64±0.02	0.62±0.01	6.36±0.01	6.24±0.01	0.93±0.03	0.90±0.02
6	0.73±0.01	0.71±0.01	6.58±0.03	6.45±0.03	0.83±0.06	0.80±0.04
7	0.31±0.02	0.30±0.01	6.58±0.01	6.45±0.01	0.96±0.03	0.93±0.02
8	0.92±0.05	0.89±0.03	6.37±0.01	6.25±0.01	1.04±0.01	1.01±0.00
9	0.56±0.05	0.54±0.03	6.46±0.01	6.33±0.01	1.02±0.02	0.99±0.01
10	0.61±0.02	0.59±0.01	5.67±0.02	5.56±0.02	0.69±0.05	0.67±0.03
11	0.61±0.02	0.59±0.01	6.34±0.02	6.21±0.02	1.04±0.02	1.01±0.01
12	0.52±0.02	0.51±0.01	6.29±0.02	6.16±0.01	0.90±0.01	0.87±0.01
13	0.91±0.03	0.88±0.02	6.40±0.01	6.27±0.01	0.90±0.06	0.87±0.03
14	0.73±0.02	0.71±0.01	6.50±0.01	6.37±0.01	0.84±0.00	0.82±0.00
15	0.54±0.00	0.52±0.00	5.66±0.02	5.55±0.02	0.70±0.00	0.68±0.00
16	0.28±0.03	0.27±0.02	6.88±0.03	6.75±0.02	0.61±0.02	0.59±0.01
17	0.28±0.01	0.27±0.01	6.86±0.01	6.72±0.01	0.82±0.02	0.79±0.01
18	0.22±0.02	0.21±0.01	6.79±0.02	6.65±0.01	0.81±0.02	0.79±0.01
19	0.23±0.00	0.23±0.00	6.75±0.01	6.62±0.01	0.92±0.02	0.89±0.01
20	0.32±0.02	0.31±0.01	6.59±0.02	6.46±0.02	0.89±0.04	0.87±0.02
M	0.53±0.02	0.51±0.03	6.45±0.04	6.32±0.31	0.83±0.02	0.81±0.02

S: Sample; M: Means; BRP: Baked rice pudding, NBRP: Non-baked rice pudding

Table 4. The amount of HMF, sucrose and lactose in Hamsiköy rice pudding samples

S	HMF(mg / 100g)		Sucrose(%)		Lactose(%)	
	BRP	NBRP	BRP	NBRP	BRP	NBRP
1	0.93±0.02	0.23±0.01	13.38±0.01	12.01±0.11	5.33±0.13	3.76±0.03
2	0.81±0.04	0.23±0.01	13.30±0.01	14.33±0.06	5.05±0.12	4.48±0.02
3	0.67±0.02	0.23±0.01	12.85±0.02	12.90±0.00	5.19±0.10	4.04±0.00
4	0.64±0.01	0.24±0.01	12.64±0.03	13.00±0.01	5.33±0.02	4.07±0.00
5	0.75±0.03	0.22±0.01	13.30±0.03	10.87±0.05	5.01±0.06	3.40±0.01
6	0.68±0.00	0.22±0.01	12.25±0.04	11.99±0.03	4.00±0.08	3.75±0.01
7	0.70±0.02	0.23±0.01	12.67±0.05	12.64±0.01	3.49±0.02	3.95±0.00
8	0.88±0.01	0.23±0.01	12.54±0.06	12.54±0.11	3.63±0.41	3.92±0.03
9	0.59±0.01	0.24±0.01	12.47±0.01	13.64±0.01	3.51±0.03	4.27±0.00
10	0.74±0.01	0.23±0.01	12.60±0.05	12.41±0.01	3.58±0.09	3.88±0.00
11	0.70±0.01	0.23±0.01	12.52±0.03	14.51±0.02	3.56±0.07	4.54±0.00
12	1.05±0.02	0.23±0.01	12.79±0.01	12.66±0.07	3.87±0.05	3.96±0.02
13	0.86±0.03	0.22±0.01	13.42±0.01	11.83±0.03	3.65±0.07	3.70±0.01
14	0.57±0.08	0.24±0.01	12.93±0.01	10.34±0.04	3.58±0.01	3.23±0.01
15	0.69±0.05	0.24±0.01	13.25±0.02	11.47±0.04	3.66±0.03	3.59±0.01
16	0.76±0.06	0.24±0.01	13.12±0.02	10.60±0.04	3.58±0.02	3.31±0.01
17	1.02±0.01	0.23±0.01	12.98±0.03	12.85±0.03	3.70±0.05	4.02±0.01
18	0.89±0.02	0.24±0.01	12.63±0.03	10.62±0.02	3.68±0.01	3.32±0.00
19	0.70±0.03	0.25±0.01	12.78±0.06	10.82±0.07	3.54±0.01	3.39±0.02
20	0.84±0.04	0.24±0.01	13.50±0.07	10.89±0.01	3.78±0.02	3.41±0.00
M	0.77±0.05	0.23±0.01	12.91±0.08	12.15±0.15	4.04±0.04	3.80±0.05

S: Sample; M: Means; BRP: Baked rice pudding, NBRP: Non-baked rice pudding

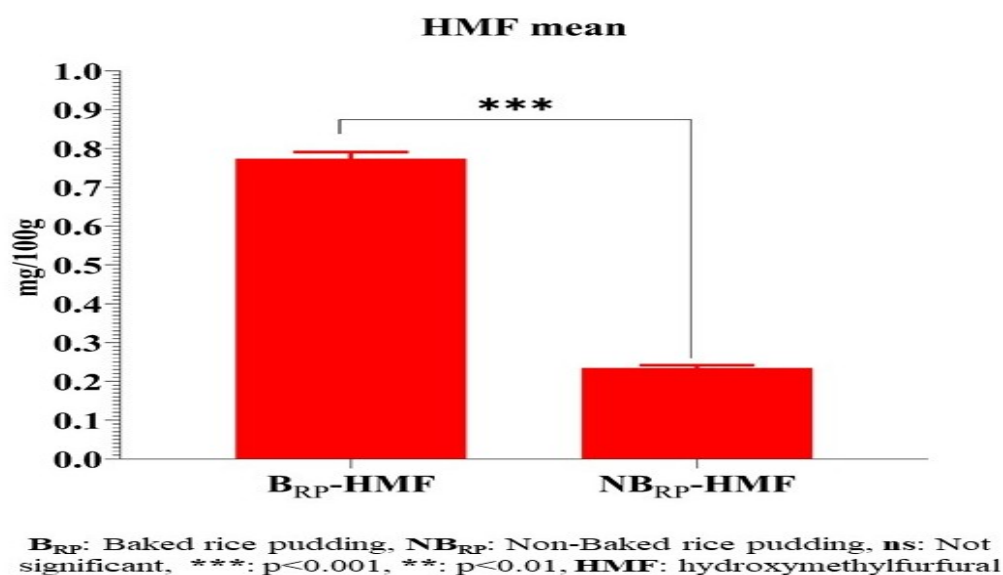


Figure 4. The means of HMF amount in Hamsiköy rice pudding samples

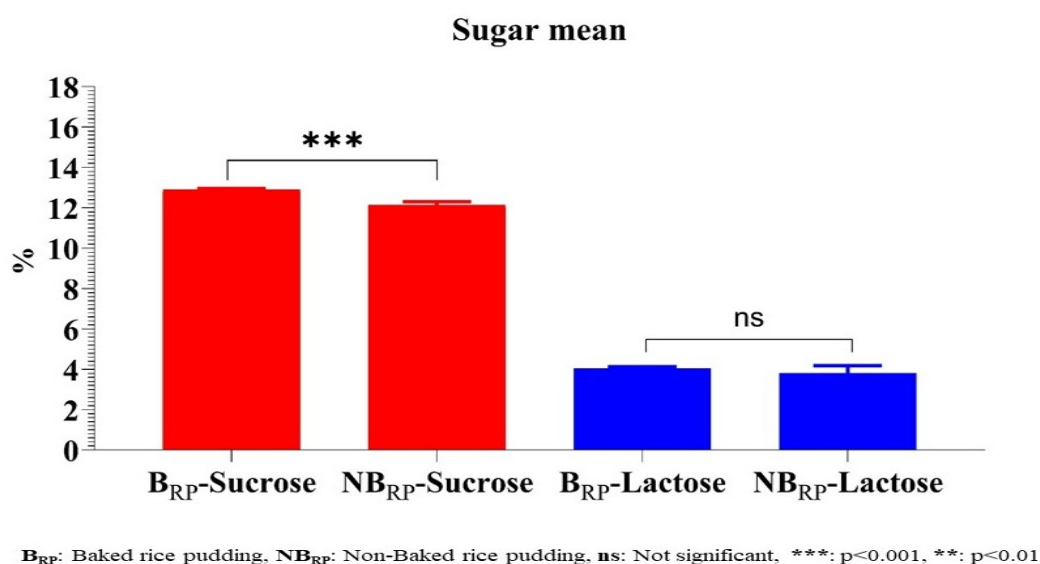


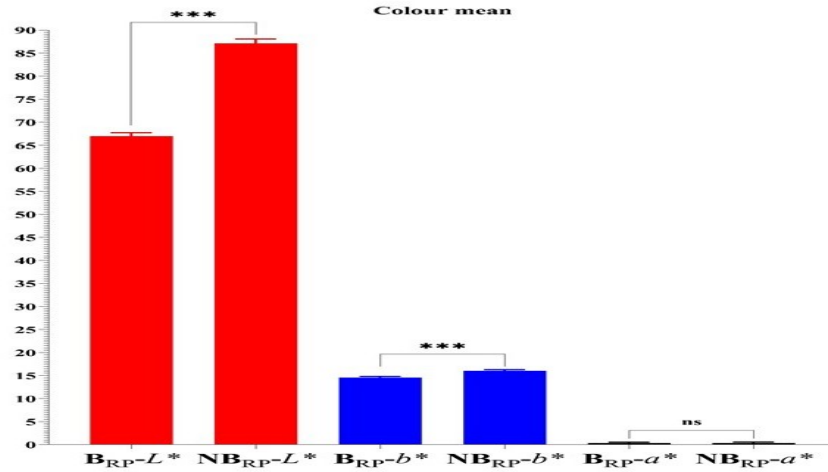
Figure 5. The mean of sugar content in Hamsiköy rice pudding samples

In addition, the average HMF, sucrose and lactose contents of the rice pudding samples are shown in Figure 5 and Figure 6. The results indicated that the level of HMF in the baked rice pudding sample was higher than in the other samples ($p < 0.001$). It has been reported that the level of HMF in heat-treated kadayif dessert increases with increasing temperature (Seyyedcheraghi et al., 2019). In the previous study (Seyyedcheraghi et al., 2023), the amount of HMF detected in the control sample was found to be at a lower level than that detected in the present research. In a separate study (Gumul et al., 2023), the level of HMF in dessert samples was found to exceed the results obtained in the present research. Observations indicated elevated levels of sucrose and lactose in baked rice pudding samples. However, while the sucrose level in the baked rice pudding samples exhibited statistically significant differences, the lactose levels did not demonstrate a statistically significant difference.

The color values of the Hamsiköy rice pudding samples are given in Table 5. In addition, the comparison of the

average color values of the rice pudding samples is shown in Figure 7. The non-baked rice pudding samples had higher L^* and b^* values when the colour values of the rice pudding samples were analyzed ($p < 0.001$). However, an analysis of the a^* values revealed that the two sample groups of rice pudding were almost identical ($p > 0.001$).

In baked rice puddings (B_{RP}), the significantly lower L^* value compared to non-baked rice puddings (NB_{RP}) (67.00 vs. 87.10) indicates that thermal processing causes a darkening of the product colour. This phenomenon can be attributed to the reactions that occur during thermal processing, including Maillard reactions and caramelisation. The reactions between proteins and reducing sugars present in the milk content result in the formation of brown pigments on the product surface. Concurrently, marginal variations in the a^* and b^* values suggest a modest enhancement in reddish and yellowish hues during the baking process (Lohinova et al. 2024).



BRP: Baked rice pudding, NB RP: Non-Baked rice pudding, ns: Not significant, ***: $p < 0.001$, **: $p < 0.01$

Figure 6. The means of colour values in Hamsiköy rice pudding samples

Table 5. The colour level of Hamsiköy rice pudding samples

S	L*		a*		b*	
	BRP	NB RP	BRP	NB RP	BRP	NB RP
1	64.08±0.33	83.30±0.25	1.34±0.19	1.41±0.11	15.94±0.74	17.53±0.47
2	55.79±1.59	72.52±1.19	2.71±0.11	2.85±0.06	14.16±0.99	15.57±0.63
3	57.83±1.76	75.17±1.32	2.15±0.14	2.25±0.09	14.43±2.23	15.87±1.42
4	61.68±0.10	80.17±0.08	1.45±0.12	1.52±0.07	15.33±0.06	16.86±0.03
5	59.11±0.54	76.84±0.41	0.03±0.06	0.04±0.04	13.08±0.26	14.38±0.17
6	62.37±0.53	81.08±0.39	2.38±0.17	2.50±0.10	17.60±0.14	19.36±0.09
7	72.60±0.15	94.38±0.11	-0.25±0.17	-0.27±0.10	14.32±0.30	15.75±0.19
8	75.09±0.21	97.62±0.16	-0.46±0.15	-0.48±0.09	14.51±0.30	15.96±0.19
9	65.64±0.15	85.34±0.11	1.97±0.25	2.07±0.15	15.89±0.53	17.48±0.34
10	64.37±1.19	83.69±0.90	1.06±0.24	1.11±0.14	15.58±0.73	17.14±0.48
11	69.21±0.58	89.98±0.44	1.97±0.29	2.07±0.17	17.47±0.23	19.22±0.15
12	63.10±0.80	82.03±0.60	1.74±0.20	1.83±0.12	14.67±0.35	16.13±0.22
13	66.70±0.35	86.71±0.26	-0.56±0.08	-0.58±0.05	12.86±0.72	14.14±0.46
14	74.93±0.16	97.40±0.12	-0.94±0.11	-0.40±0.06	15.52±0.01	17.08±0.01
15	69.56±0.26	90.42±0.20	-1.76±0.04	-1.84±0.02	10.56±0.58	11.61±0.37
16	69.25±0.13	90.02±0.10	-2.07±0.05	-2.18±0.03	11.07±0.04	12.17±0.02
17	69.78±0.24	90.71±0.18	-0.40±0.02	-0.42±0.02	13.93±0.07	15.32±0.05
18	71.95±0.10	93.54±0.07	-1.83±0.02	-1.93±0.02	12.73±0.04	14.00±0.02
19	73.38±0.01	95.40±0.01	-1.45±0.01	-1.53±0.00	15.73±0.02	17.30±0.01
20	73.64±0.02	95.74±0.01	-0.87±0.04	-0.92±0.02	16.08±0.01	17.68±0.01
M	67.00±0.75	87.10±0.97	0.34±0.19	0.35±0.21	14.57±0.24	16.03±0.27

S: Sample; M: Means; BRP: Baked rice pudding, NB RP: Non-baked rice pudding

Conclusion

This study evaluated the microbiological and physicochemical quality of Hamsiköy rice pudding samples, highlighting the influence of baking on safety and product quality. Baking notably reduced microbial loads, particularly coliforms, *Enterobacteriaceae*, and *Pseudomonas spp.*, while enhancing physicochemical attributes such as protein, fat, and colour stability. These findings demonstrate that baking not only improves sensory characteristics but also strengthens food safety. To ensure consistent safety and quality, the implementation of Good Manufacturing Practices (GMP) and Hazard Analysis Critical Control Points (HACCP) systems in Hamsiköy rice pudding production is strongly recommended.

Declaration

Author Contribution Statement

G.O.: Formal Analysis; Investigation; Methodology; Writing - review & editing. **F.Y.:** Conceptualization; Data curation; Investigation; Resources; Writing - original draft; Writing - review & editing. Formal analysis.

Declaration of competing interest

The authors declared that there is no conflict of interest.

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