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Research Article

Microbial quality of sesame products produced in Ardakan County, Iran

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Abstract

Sesame-based products, particularly tahini and tahini halva, are widely consumed in Iran and other Middle Eastern countries. Ardakan County is a major production center for these products; therefore, monitoring their hygiene and spoilage indicators is essential. This study evaluated the microbial quality of sesame products produced in Ardakan County, Iran. In this cross-sectional study, 150 sesame product samples (68 tahini, 42 tahini halva, 20 chocolate tahini, and 20 sesame cream) were collected from 20 workshops and retail outlets in Ardakan County from autumn to winter 2023. Samples were examined for *Escherichia coli*, coliforms, yeasts, and molds using Iran National Standards Organization methods. Results were interpreted according to relevant Iranian microbiological criteria. No *E. coli* or coliforms were detected in any of the 150 samples. Yeast and mold counts were < 10 CFU/g in 127 samples (84.7%); however, the specific samples positive for yeasts and molds were not necessarily identical. Detectable levels (≥ 10 CFU/g) were found in 23 samples (15.3%) for both yeasts (10–40 CFU/g) and molds (10–200 CFU/g) in this study. Only one tahini sample exceeded the 100 CFU/g mold limit, resulting in an overall compliance rate of 99.3%. Sesame products produced in Ardakan County showed satisfactory hygienic quality regarding the evaluated indicators with respect to *E. coli*, coliforms, yeasts, and molds. The absence of fecal hygiene indicators suggests acceptable sanitary control during production; however, the detection of fungi in some samples indicates the need for continued good hygienic practices and routine microbiological monitoring.

Keywords: Coliforms, *Escherichia coli*, Molds, Sesame products, Tahini, Yeasts.

Introduction

Sesame (*Sesamum indicum* L.) is one of the oldest cultivated oilseed crops and is widely used in food systems because of its high oil content, nutritional value, and technological functionality. Sesame seeds contain considerable amounts of lipids, proteins, carbohydrates, minerals, vitamins, lignans, tocopherols, and phytosterols, which contribute to the nutritional and functional importance of sesame-derived foods (Kollia et al., 2016; Lee et al., 2020; Yao et al., 2021). In addition to direct seed consumption, sesame is processed into several products, including tahini, sesame oil, tahini halva, sesame cream, and sesame-based confectionery products (Namiki, 2007).

Tahini, locally known as Ardeh in Iran, is a viscous paste obtained from dehulled, roasted, and ground sesame seeds. Tahini halva is generally produced by mixing tahini with sugar syrup and other ingredients, such as citric or tartaric acid and

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saponaria extract, resulting in a dense, energy-rich confectionery product (Osaili et al., 2018). These products are widely consumed in Iran, Turkey, Arab countries, and other parts of the Middle East and are increasingly marketed internationally because of their nutritional value and sensory acceptability (Anilakumar et al., 2010; Namiki, 2007).

Ardakan County, located in Yazd Province in central Iran, is an important center for sesame-based product production. The local production of tahini and tahini halva has economic and cultural importance, and these products are distributed both locally and beyond the region. Because these foods are often produced in small workshops or semi-industrial settings, continuous evaluation of their microbiological quality is important to ensure product safety, protect public health, and maintain consumer trust. Although sesame products are generally considered relatively stable because of their low moisture content, high fat content, heat treatment during processing, and, in some formulations, high sugar concentration, microbial contamination can still occur. Low-water-activity foods have been increasingly recognized as potential vehicles for foodborne pathogens, and some pathogens may survive for long periods in dry or high-fat matrices (Beuchat et al., 2013; Kotzekidou, 1998). Recent reviews and regulatory reports have linked sesame-based products, particularly tahini and halva, to *Salmonella* outbreaks and recalls (Unicomb et al., 2005; Coulombe and Tamber, 2022; Canadian Food Inspection Agency, 2025). Therefore, sesame products should not be considered microbiologically risk-free.

Contamination may originate from raw sesame seeds, added ingredients, water, equipment, production surfaces, packaging materials, food handlers, or post-processing exposure. Roasting is an important microbial reduction step in tahini production; however, survival or post-processing contamination remains possible if processing, storage, or hygiene conditions are not adequately controlled (Torlak et al., 2013). Fungal contamination is also relevant because molds and yeasts may affect shelf life, sensory quality, and, in the case of some molds, potential mycotoxin risk.

Among microbiological indicators, *Escherichia coli* and coliforms are commonly used to assess fecal contamination, sanitary handling, and hygiene. The presence of *E. coli* in ready-to-eat foods is particularly important because it indicates inadequate hygiene, possible fecal contamination or post-processing contamination. Yeasts and molds are also relevant in sesame products because they may indicate inadequate control of raw materials, storage conditions, packaging, and environmental sanitation.

Previous studies have reported variable microbial quality in sesame-based and traditional confectionery products. Contamination with coliforms, *E. coli*, yeasts, molds, *Salmonella*, *Staphylococcus aureus*, or *Bacillus cereus* has been reported in some tahini halva and related products, whereas other studies have reported low contamination levels or absence of major pathogens (Ayaz et al., 1986; Kahraman et al., 2010; Alaouie et al., 2018; Var et al., 2020; Compaoré et al., 2021; Kilci and Çetin, 2022; Barmettler et al., 2025). These differences may reflect variations in raw materials, processing conditions, hygienic practices, packaging, storage, season, and regional production systems.

Despite the importance of Ardakan as a production center for sesame products, limited recent data are available on the microbiological quality of different sesame product categories produced in this region. Therefore, this study aimed to evaluate the microbial quality of tahini, tahini halva, chocolate tahini, and sesame cream produced in Ardakan County, Iran, with a specific focus on *E. coli*, coliforms, yeasts, and molds.

Materials and Methods

Study design and sampling area

This cross-sectional descriptive study was conducted to evaluate the microbiological quality of sesame products produced and supplied in Ardakan County, Yazd Province, Iran. Sampling was conducted from early autumn to late winter 2023. Ardakan County was selected because it is one of the main centers of sesame product production in Iran and has numerous workshops and production units for tahini and tahini halva.

Sample collection

A total of 150 sesame-product samples were collected from 20 workshops, production centers, distribution centers, and retail outlets in Ardakan County. The samples consisted of tahini (n = 68), tahini halva (n = 42), chocolate tahini (n = 20), and sesame cream (n = 20). The difference in the number of samples across product types reflects their relative availability in the sampled centers; tahini is a staple product produced in almost all workshops, whereas chocolate tahini and sesame cream are produced in fewer facilities. Sampling was performed randomly across the 20 workshops, and the number of samples collected from each facility was approximately proportional to its production volume and variety (**Table 1**). Samples were collected aseptically directly from the food product in the production equipment or containers (not from surface swabs) using sterile instruments and sterile containers. Therefore, the measurement unit was CFU/g. After collection, the samples were transported in insulated boxes with ice packs (approximately 4 °C) to the Bacteriology Laboratory, Faculty of Veterinary Medicine, Ardakan University. Upon arrival, they were immediately analyzed for *E. coli*, coliforms, yeasts, and molds.

Table 1. Distribution of sesame-product samples collected from different workshops and retail outlets in Ardakan county, Iran.

Facility ID	Tahini Halva (n)	Tahini (n)	Sesame Cream (n)	Chocolate Tahini (n)	Total (n)
1	2	3	0	0	5
2	3	4	0	0	7
3	3	3	2	2	10
4	1	3	1	1	6
5	3	2	1	1	7
6	2	4	0	2	8
7	3	3	2	0	8
8	1	3	1	1	6
9	3	2	2	2	9
10	4	4	1	1	10
11	2	4	2	0	8
12	2	3	1	1	7
13	3	4	0	2	9
14	2	4	1	2	9
15	2	3	1	2	8
16	1	3	0	0	4
17	2	4	2	0	8
18	1	4	2	1	8
19	1	4	0	1	6
20	2	4	1	1	8
Total	**42**	**68**	**20**	**20**	**150**

Culture media and laboratory materials

Microbiological analyses were performed using standard culture media appropriate for each target group. All culture media used in this study were purchased from Ibresco (Tehran, Iran). Lauryl sulfate broth, EC broth, indole broth, and MacConkey agar were used for detection and confirmation of *E. coli*. Violet Red Bile Lactose (VRBL) agar and brilliant green bile broth were used for coliform enumeration and confirmation. Yeast glucose chloramphenicol (YGC) agar was used as a single medium for the simultaneous enumeration of both yeasts and molds.

Sample preparation

For the initial 1:10 dilution, 10 g of each sesame-product sample was aseptically weighed and homogenized with 90 mL of 0.1% Peptone Water (Ibresco, Tehran, Iran) using a shaker (Arminad,

Tehran, Iran) at medium speed (15 min). This step ensured proper dispersion of the high-fat and viscous matrices before further serial dilutions.

Detection of *E. coli*

Detection of *E. coli* was performed according to Iran National Standards Organization (INSO, 2005) methods (INSO 2946). An initial 1:10 sample dilution was prepared under aseptic conditions, and 10 mL of this dilution was inoculated into 10 mL of double-strength lauryl sulfate broth. The tubes were incubated at 37 °C for 48 h. Tubes showing turbidity and gas production in Durham tubes were transferred to EC broth and incubated at 44 °C for 48 h. Presumptive positive cultures were then transferred to indole broth and incubated at 44 °C for 24 h. Kovac's reagent was added, and formation of a pink ring was considered a positive indole reaction and confirmation of *E. coli*. The detection was performed qualitatively (presence/absence) following the INSO 2946 protocol without calculating the numerical MPN value. The indole test served as the confirmatory step according to the standard procedure.

Enumeration of coliforms

Coliforms were enumerated according to Iran National Standards Organization (INSO, 2007) methods (INSO 9263) using the pour-plate method. A 1:10 sample dilution was prepared and inoculated onto VRBL agar. Plates were incubated at 37 °C for 24 h. Red-purple colonies with a diameter of at least 0.5 mm were considered typical coliform colonies. For confirmation, five typical colonies were inoculated into brilliant green bile lactose broth and incubated at 37 °C for 24 h. Turbidity and gas production in Durham tubes were considered confirmatory for coliforms. Counts were calculated and expressed as CFU/g. Plates with 10 to 150 colonies were selected for counting. The CFU/g was calculated using the standard formula. Plates with no colonies were reported as < 10 CFU/g, and plates with excessive growth were excluded from the calculation.

Enumeration of yeasts and molds

Yeasts and molds were enumerated according to Iran National Standards Organization (INSO, 2013) methods (INSO 10899-3). This method was selected considering the low-water-activity characteristics reported for similar sesame products, including tahini and tahini halva (Barmettler et al., 2025). Previous research on a material used in tahini halva production has also cited INSO 10899-3 for sample dilution and fungal enumeration procedures (Kamali et al., 2025). Serial decimal dilutions were prepared from each sample, inoculated onto YGC agar using the pour-plate method, and incubated at 25 °C for 5 days. Colonies were counted after incubation, and results were expressed as CFU/g. When no colonies were observed, results were reported as below the detection limit of 10 CFU/g.

Microbiological criteria

The results were interpreted according to the Iranian national microbiological criteria for confectionery products (INSO 2395). For tahini, the reference limits were 50 CFU/g for coliforms, absence of *E. coli*, and 100 CFU/g for yeasts and molds, respectively. For tahini halva and sesame cream, the reference limits were absence of *E. coli*, 100 CFU/g for molds, and 100 CFU/g for yeasts. Chocolate tahini was evaluated as a tahini-based sesame product using the relevant sesame-product microbiological criteria, which were the same as those applied to tahini: absence of *E. coli*, ≤ 50 CFU/g coliforms, and ≤ 100 CFU/g yeasts and molds.

Statistical analysis

The results were summarized descriptively as frequencies, percentages, and CFU/g distributions by product type. Because the objective of the study was a descriptive microbiological evaluation and most bacterial indicators were negative across all samples, no inferential statistical comparison was performed. Frequency distributions were used to compare contamination patterns among tahini, tahini halva, chocolate tahini, and sesame cream samples.

Results and Discussion

Sample distribution

A total of 150 sesame-product samples were examined. Tahini represented the largest proportion of samples (45.3%), followed by tahini halva (28.0%), chocolate tahini (13.3%), and sesame

cream (13.3%) (**Table 2**). This distribution reflects the relative availability of products in the sampled workshops, production centers, and retail outlets in Ardakan County.

***Escherichia coli* and coliforms**

None of the 150 sesame product samples were positive for *E. coli*. Similarly, coliform bacteria were not detected in any sample (**Table 3**). Therefore, all tested samples complied with the Iranian national microbiological criteria regarding absence of *E. coli*. Tahini samples also complied with the coliform criterion.

The absence of *E. coli* and coliforms indicates satisfactory hygienic control in the sampled production and supply chain and supports compliance with the evaluated bacterial criteria. This result is more favorable than reports in which *E. coli*, coliforms, or Enterobacteriaceae were detected in tahini, tahini halva, and similar products (Kahraman et al., 2010; Alaouie et al., 2018; Var et al., 2020), but is consistent with studies reporting absence of *E. coli* in sesame or tahini halva samples (Aydın and Başaran, 2018; Compaoré et al., 2021; Kilci and Çetin, 2022). However, these findings only address selected hygiene indicators. Recent studies and outbreak reviews show that *Salmonella* and *B. cereus* remain relevant hazards in sesame products, and that stressed pathogens may require validated control steps in tahini matrices (Coulombe and Tamber, 2022; Osaili et al., 2021; Barmettler et al., 2025; Sengun et al., 2005).

Table 2. Distribution of sesame-product samples collected from Ardakan County, Iran

Product type	Number of samples	Percentage (%)
Tahini	68	45.3
Tahini halva	42	28.0
Chocolate tahini	20	13.3
Sesame cream	20	13.3
Total	150	99.9

Table 3. Summary of microbiological findings in sesame products produced in Ardakan County, Iran

Product type	n	*E. coli* positive n (%)	Coliform positive n (%)	Yeast ≥10 CFU/g n (%)	Mold ≥ 10 CFU/g n (%)	Non-compliant samples n (%)
Tahini	68	0 (0.0)	0 (0.0)	7 (10.3)	9 (13.2)	1 (1.5)
Tahini halva	42	0 (0.0)	0 (0.0)	6 (14.3)	4 (9.5)	0 (0.0)
Chocolate tahini	20	0 (0.0)	0 (0.0)	6 (30.0)	6 (30.0)	0 (0.0)
Sesame cream	20	0 (0.0)	0 (0.0)	4 (20.0)	4 (20.0)	0 (0.0)
Total	**150**	**0 (0.0)**	**0 (0.0)**	**23 (15.3)**	**23 (15.3)**	**1 (0.7)**

Note: Non-compliance was interpreted according to the evaluated Iranian microbiological criteria for the tested sesame products. The only non-compliant result was one tahini sample with 200 CFU/g mold. CFU = Colony-Forming Unit.

Yeast contamination

Table 4 presents the frequency distribution of yeasts and molds in the examined sesame products. Yeast counts were generally low in all product categories. Among 68 tahini samples, 61 samples (89.7%) had yeast counts < 10 CFU/g, and seven samples (10.3%) had 10 CFU/g. Among 42 tahini halva samples, 36 samples (85.7%) had yeast counts < 10 CFU/g, and six samples (14.3%) had 10 CFU/g.

Chocolate tahini showed the highest frequency of detectable yeasts: 14 samples (70.0%) had < 10 CFU/g, four samples (20.0%) had 10 CFU/g, one sample (5.0%) had 20 CFU/g, and one sample (5.0%) had 40 CFU/g. In sesame cream, 16 samples (80.0%) had <10 CFU/g, two samples (10.0%) had 10 CFU/g, and two samples (10.0%) had 20 CFU/g (**Table 4**). Overall, yeasts were detectable at ≥ 10 CFU/g in 23 samples (15.3%), but all yeast counts were below the 100 CFU/g criterion.

Mold contamination

Mold counts were low in most of the samples. Among the tahini samples, 59 (86.8%) had mold counts < 10 CFU/g, five (7.4%) had 10 CFU/g, and four had higher counts of 30, 60, 90, and 200 CFU/g. Among the tahini halva samples, 38 (90.5%) had < 10 CFU/g, three (7.1%) had 10 CFU/g, and one (2.4%) had 20 CFU/g. Among the chocolate tahini samples, 14 (70.0%) had < 10 CFU/g, five (25.0%) had 10 CFU/g, and one (5.0%) had 30 CFU/g. Among the sesame cream samples, 16 (80.0%) had < 10 CFU/g, two (10.0%) had 10 CFU/g, and two (10.0%) had 20 CFU/g (**Table 4**). The frequency of mold detection at ≥ 10 CFU/g was also 23 samples (15.3%); however, it is important to note that these were not necessarily the same samples that tested positive for yeast. Only one tahini sample (200 CFU/g) exceeded the 100 CFU/g limit.

Table 4. Frequency distribution of yeast and mold counts in sesame products produced in Ardakan County, Iran

Product type	Microbial group	< 10 CFU/g n (%)	10 CFU/g n (%)	20 CFU/g n (%)	30 CFU/g n (%)	40 CFU/g n (%)	60 CFU/g n (%)	90 CFU/g n (%)	200 CFU/g n (%)
Tahini	Yeast	61 (89.7)	7 (10.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
	Mold	59 (86.8)	5 (7.4)	0 (0.0)	1 (1.5)	0 (0.0)	1 (1.5)	1 (1.5)	1 (1.5)
Tahini halva	Yeast	36 (85.7)	6 (14.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
	Mold	38 (90.5)	3 (7.1)	1 (2.4)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Chocolate tahini	Yeast	14 (70.0)	4 (20.0)	1 (5.0)	0 (0.0)	1 (5.0)	0 (0.0)	0 (0.0)	0 (0.0)
	Mold	14 (70.0)	5 (25.0)	0 (0.0)	1 (5.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Sesame cream	Yeast	16 (80.0)	2 (10.0)	2 (10.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
	Mold	16 (80.0)	2 (10.0)	2 (10.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Total	**Yeast**	**127 (84.7)**	**19 (12.7)**	**3 (2.0)**	**0 (0.0)**	**1 (0.7)**	**0 (0.0)**	**0 (0.0)**	**0 (0.0)**
	Mold	**127 (84.7)**	**15 (10.0)**	**3 (2.0)**	**2 (1.3)**	**0 (0.0)**	**1 (0.7)**	**1 (0.7)**	**1 (0.7)**

Low yeast and mold counts observed in this study indicate generally acceptable mycological quality. Detectable fungi in a subset of samples may still reflect contamination from raw sesame seeds, flavoring ingredients, equipment, airborne spores, packaging materials, or storage conditions. Because post-processing contamination can occur after roasting or heating, sanitation of production surfaces, environmental hygiene, and packaging control remain important.

Compared with the Sohan samples studied by Mashak et al. (2014), which showed higher mold and yeast counts, the maximum counts in the present study were notably lower. This difference might be explained by variations in the product matrix (Sohan is a dry, baked confectionery, while tahini is a high-fat paste), as well as variations in the hygienic practices of the production units and storage conditions. Nevertheless, direct comparisons should be made with caution because of differences in sampling seasons and regional production systems.

The proportion of samples with detectable yeasts and molds was highest in chocolate tahini, but the detected counts remained low. The higher frequency of detectable yeasts in chocolate tahini compared to other products could be attributed to the addition of cocoa powder, sugar, and other flavoring ingredients, which may introduce additional microbial loads. Furthermore, the greater formulation complexity and additional handling steps during the mixing of chocolate tahini increase the risk of post-processing contamination. In contrast, the lower fungal counts in tahini and tahini halva may be due to their higher fat content and

lower water activity, which limit microbial proliferation. However, the highest single mold count was observed in tahini. As tahini is the base ingredient for many sesame products, fungal contamination at this stage may influence downstream products if not properly controlled. Therefore, control of raw sesame quality, roasting conditions, equipment sanitation, and packaging hygiene is critical.

The presence of one tahini sample with a mold count of 200 CFU/g (exceeding the 100 CFU/g limit) indicates that even with adequate roasting, post-processing contamination or the use of contaminated raw seeds remains critical. This highlights the vulnerability of small-scale production lines to environmental contamination, emphasizing the necessity of strict good hygiene practice (GHP) implementation, particularly the sanitation of grinding and filling equipment.

From a regulatory perspective, the results were satisfactory for nearly all samples. All samples were compliant for *E. coli* and coliform indicators, and all yeast counts were below the permitted limit. Mold counts were also below the relevant limit in all samples except one tahini sample. Therefore, 149 of 150 samples (99.3%) were compliant with the evaluated microbiological criteria. This finding supports the overall acceptable microbiological status of sesame products produced in the sampled centers in Ardakan County.

Potential control points for sesame products

Although the present study was not designed as a formal Hazard Analysis and Critical Control Point (HACCP) analysis, the results and current literature indicate several potential control points that require attention in sesame-product production. These include the microbiological quality of raw sesame seeds and added ingredients, use of potable water during washing and dehulling, validated roasting or heat treatment, prevention of post-roasting cross-contamination during grinding, mixing, filling, and packaging, sanitation of food-contact surfaces, employee hygiene, and control of packaging and storage humidity. These points are particularly important because *Salmonella* has been repeatedly associated with sesame-based products, and recent food-safety guidance emphasizes validated heat treatment and prevention of cross-contamination after roasting (Canadian Food Inspection Agency, 2025).

Given that Ardakan County hosts numerous semi-industrial and traditional workshops, the high compliance rate (99.3%) is an encouraging sign of the local producers' adherence to basic hygiene. However, the occasional presence of fungi suggests that seasonal fluctuations in storage temperature or inconsistent packaging quality during distribution in Yazd Province may still pose risks. Therefore, implementing formal HACCP-based training for local producers is highly recommended.

Nevertheless, several limitations should be considered. First, the study focused on selected hygiene and spoilage indicators and did not include important foodborne pathogens such as *Salmonella* spp., *S. aureus*, and *B. cereus*; therefore, the absence of *E. coli* and coliforms does not guarantee the absolute microbiological safety of the products. Second, physicochemical parameters such as water activity, pH, moisture content, and packaging conditions were not assessed, although these factors strongly influence microbial survival and growth in low-moisture foods. Third, sampling was conducted from autumn to winter; therefore, seasonal changes, especially during warmer months, could not be evaluated. Future studies should include broader pathogen screening, physicochemical characterization, seasonal sampling, and formal HACCP-based assessment of the proposed control points. Fourth, water activity (aw) was not directly measured in this study; it was assumed to be < 0.6 based on previous literature for tahini and halva, which might be a limitation for chocolate tahini and sesame cream. Additionally, mycotoxin analysis (e.g., aflatoxin B1) was not performed in this study; therefore, the presence of molds does not necessarily indicate mycotoxin contamination, nor does the absence of culturable molds guarantee the absence of mycotoxins.

Conclusion

Sesame products produced and supplied in the sampled centers of Ardakan County showed acceptable microbiological quality with respect to

the evaluated hygiene and spoilage indicators. *E. coli* and coliforms were not detected in any sample, indicating satisfactory sanitary control and the absence of fecal hygiene indicators in the examined products. Yeast and mold counts were generally low, and almost all samples complied with the evaluated Iranian microbiological criteria. The only non-compliant finding was one tahini sample with a mold count above the permitted limit. These findings suggest that the current hygienic status of sesame product production in the sampled centers is generally favorable. Nevertheless, the detection of fungi in some samples highlights the need for continued application of GHP, control of raw sesame quality, sanitation of production equipment, appropriate packaging, and routine microbiological monitoring. Future studies should include broader pathogen detection, physicochemical parameters such as water activity and moisture content, and seasonal sampling to provide a comprehensive evaluation of sesame-product safety.

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Conflicts of interest

There is no conflict of interest.

Disclaimer

ChatGPT (OpenAI) was used to assist with language editing and improving the clarity and readability of the manuscript. The authors have reviewed and revised the AI-assisted text and take full responsibility for the accuracy, originality, and integrity of the manuscript.

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