Research Article
Journal of Agricultural Biotechnology (JOINABT) 2(2), 56-65, 2021
Recieved: 25-Nov-2021 Accepted: 25-Dec-2021

SAKARYA UNIVERSITY
OF APPLIED SCIENCES

The Effects of Different Drying and Packaging Applications on the Microbiological Properties of Sliced Figs

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ABSTRACT

In this research, two different drying and packaging methods were applied to the Sarılop cultivar figs obtained from Aydın province. Some quality criteria of dried figs were followed during storage. Figs were dried traditionally under the sun and by lyophilization, and dried product was packed conventionally and under nitrogen gas and stored in room conditions (25℃) for 6 months. Chemical (total titratable acidity, total sugar, ash, dry matter), physical (color) and microbial (total mesophilic aerobic bacteria, mold and yeast, coliform group bacteria) analyses were done on fresh and dried figs. Total bacteria and total coliform bacteria counts were higher in freeze-dried figs (6.57 log cfu g^{-1}; 4.32 log cfu g^{-1}) than the ones dried under the sun (5.13 log cfu g^{-1}; 3.76 log cfu g^{-1}). In contrast, yeast and mold counts were higher in sun-dried figs (5.69 log cfu g-1). It was determined that microbial load decreased with storage under room conditions for 6 months, and these values were lower in dried figs packed with nitrogen. It also was determined that the color values were better preserved in lyophilized samples packed with nitrogen.

Keywords: Sarılop, dried figs, freeze-drying, sun-drying.

Farklı Kurutma ve Ambalaj Uygulamalarının Dilimlenmiş İncirlerin Mikrobiyolojik Özelliklerine Etkileri

ÖZ

Bu araştırmada, Aydın ilinden temin edilen Sarılop çeşidi incirlere iki farklı kurutma ve paketleme yöntemi uygulanmıştır. Depolama boyunca kurutulmuş incirlerin bazı kalite kriterleri takip edilmiştir. İncirler geleneksel olarak güneşte ve dondurarak kurutma yöntemleriyle kurutulmuş, son ürün direkt ve azot gazı altında paketlenerek 6 ay boyunca oda koşullarında (25℃) saklanmıştır. Taze ve kurutulmuş incir örneklerinde kimyasal (toplam titrasyon asitliği, toplam şeker, kül, kuru madde), fiziksel (renk) ve mikrobiyolojik (toplam mezofilik aerobik bakteri, küf ve maya, koliform grup bakteri) analizleri yapılmıştır. Toplam bakteri ve koliform bakteri sayılarının dondurarak kurutulmuş incirlerde (6.57 log kob g^{-1}; 4.32 log kob g^{-1}) güneşte kurutulanlardan (5.13 log kob g^{-1}; 3.76 log kob g^{-1}) daha yüksek olduğu

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belirlenmiştir. Bunun aksine, maya ve küf sayısı güneşte kurutulan incirlerde (5.69 log kob g^{-1}) daha yüksek bulunmuştur. 6 aylık oda koşullarında depolama ile mikrobiyal yükün azaldığı, azotla paketlenmiş kuru incirlerde bu değerlerin daha düşük olduğu tespit edilmiştir. Renk değerlerinin dondurarak kurutulmuş ve azot altında paketlenen örneklerde daha iyi korunduğu belirlenmiştir.

Anahtar Kelimeler: Sarılop, kuru incir, dondurarak kurutma, güneşte kurutma

1 Introduction

Fig (*Ficus carica* L.) plant belongs to the Moraceae family, which has more than 1400 species. Approximately 700 of these species are in the *Ficus* genus [1]. *F. carica* L. is an important commercial fruiting member of the genus *Ficus* [2]. Figs are commercially produced in countries where the Mediterranean climate prevails, such as California, Australia and South America, and in Mediterranean countries [3]. According to 2019 data, 1315588 tons of figs were produced in the world, and Turkey became the largest producer in the world with 310000 tons [4].

Figs are grown in almost all regions of our country, except for the Eastern Anatolia region. The coastal belt is the region where it is grown the most, thanks to its ecological harmony. Therefore, table figs are also grown in Marmara, Mediterranean, Black Sea and Southeastern Anatolia Regions [5]. The fig tree is grown in warm and dry climates [6]. 65% of the fig trees are located in the Western Aegean Region, especially in the Küçük and Büyük Menderes basins. From these basins, 75% of the fresh fig production and the total product in the dried fig export are supplied. Since the climate conditions in the region are suitable for fig cultivation, the highest quality figs are grown in these basins [7].

Dried figs are among the top traditional export products of Turkey [8]. Turkey provides approximately 60% of the world dried fig production and Aydın province provides 85% of them [5]. Generally, Sarılop cultivar is used as dried figs and is widely grown in Aydın and İzmir regions [9].

Quality dried figs according to TSE 541 [10] standard; It must be mature, sound, completely dried, clean and free of foreign matter. There should be no visible live or dead insects, rodents and other parasites, foreign matter exceeding tolerance, spoiled, sunburned, slit. It should not contain abnormal external humidity, foreign taste and odor.

Figs are consumed fresh, dried or canned, and are also used in jam making. It is a nutritious fruit with high protein content, rich in calcium (higher than milk), iron and fiber content. Its chemical composition and aroma vary according to the variety. The total sugar content of fresh figs is 16%, and dried figs are around 52%. Fresh figs (100 g) contains moisture (88.1%), protein (1.3 g), oil (0.2%), minerals (0.6%), fiber (2.2%), carbohydrates (7.6%), phosphorus (22 mg), iron (0.6 mg), vitamin A (80 IU), thiamine (0.1 mg) and calcium (35 mg). The edible part (100 g) of dried figs includes moisture (23.0 g), protein (4.3 g), oil (1.3%), minerals (2.4%), fiber (5.6%), carbohydrates (69%), phosphorus (77 mg), iron (4 mg), vitamin A (100 IU), thiamine (0.1 mg) and calcium (200 mg) [11].

The purpose of drying agricultural products is to remove the free water in the wet products and to prevent the deterioration of the food by stopping the biochemical reactions and microbial activities that may occur in the products. In addition, the decrease in the volume and weight of dried products also reduces transportation and storage costs [12]. In freeze-drying, the product to be dried is first frozen and thus the water in the food is bound in the form of ice, and then the ice is sublimated (transformation of ice into steam without melting) under appropriate conditions. The quality of the freeze-dried product is superior

to the products dried by other methods. Therefore, although it is an expensive method compared to others, it is used commercially for drying many valuable and heat sensitive products. On the other hand, the nutritional value of freeze-dried products is also higher. The reason for this is that the substances inside the cell do not disperse out of the cell and on the surface of the material as in other methods [13]. Shape, appearance, taste, nutrient content, color, texture and biological activity properties of freeze-dried samples are very close to the properties of the fresh product. For this reason, it is seen as one of the methods that affect the structure and properties of food the least. Moreover, this method reduces the risk of deterioration of the antioxidant components of the food [14].

In this study, sun and freeze drying methods were applied to Sarılop cultivar figs. Dried figs, which were packaged using two different packaging techniques, were stored under room conditions for 6 months. Physicochemical (ash determination, dry matter determination, acidity determination, moisture, color determination) and microbiological (total mesophilic aerobic bacteria, total mold and yeast, coliform bacteria) analyzes were performed in dried figs and the changes were monitored during storage.

2 Material and Methods

In these research, Sarılop (*F. carica* L.) cultivar of figs were used as material. Figs were obtained from the fig orchard located in Güzönü area, parcel no 260-41 in Nazilli district of Aydın province. All of the fruits used for the production of dried figs were collected from the same garden.

2.1 Drying Methods

Figs belonging to the Sarılop cultivar were dried using two different techniques, namely sun drying and freeze drying. After the figs were picked from the trees in the morning hours, they were transported in wooden crates. In order to remove the dust layer on the figs and to reduce the microbial load, they were washed by dipping them into a container filled with water. It was sliced into 4 mm thick round rings to ensure a homogeneous drying. In the sun drying method, it was kept on sofas made of wood or plastic, known as kerevet, for 4-7 days. In the lyophilized drying method, sliced fig samples, on which blotting paper was laid, were prepared for drying conditions by freezing them in a deep freezer at -20°C for 1 day. Then, the frozen figs were dried in a lyophilizer equipment (VirTis Freeze Dryer 2KBTES-55 Model, USA) for 24 hours. The freeze-drying (lyophilized) process was carried out at -60°C under 100 mTorr vacuum. Fresh figs prepared for drying, sun dried and lyophilized figs are shown in Figure 1. Dried figs are placed in sterile bags and packaged in two different ways, directly and under nitrogen gas. Stored at room temperature (25°C) in a dark condition.

a)  **b)**  **c)** 

Figure 1: *a) fresh figs; b) sun-dried figs; c) lyophilized figs*

2.2 Chemical Analyzes

Chemical analysis were performed initially to fig samples. The fresh and dries figs moisture content was determined by method TS 1129 ISO 1026. The amount of ash was calculated as % of the weight loss caused by burning at 500-550 °C [15]. Titration acidity was determined with 0.1 N NaOH by titrimetric method, calculating in terms of citric acid [16]. Total sugar analysis was done by Luff-Schoorl method according to Cemeroğlu [15].

2.3 Color Analyzes

Color parameters on the Hunter scale were expressed L, a, b. Negative L indicates darkness, and positive L indicates lightness, whereas negative a indicates green color, positive a indicates red color, positive b indicates yellow color, and negative b indicates blue color. Depending on these values, color clarity (Chroma) and hue values were calculated using the 1 and 2 equations. Hue value varies between 0°–360°; 0° and 360° are evaluated as red-violet, 90° yellow, 180° green and 270° blue.

$$\text{Chroma} = (a^2 + b^2)^{1/2} \quad (1)$$

$$\text{Hue} = \text{Arctan}\ (b/a) \quad (2)$$

2.4 Microbiological Analyzes

Total mesophilic aerobic bacteria, total coliform, yeast-mold counts were determined in fresh figs, and figs packed with different drying and packaging methods. Under aseptic conditions, sequential dilutions were prepared by homogenizing 5 g of sample in 45 ml of physiological saline. Eosin Methyl Blue agar (EMB) for total coliform bacteria analysis, Patato Dextrose Agar (PDA) for mold and yeast count, and Plate Count Agar (PCA) for total mesophilic aerobic bacteria count were inoculated from appropriate dilutions. PCA plates were incubated at 30°C for 24-48 hours, PDA plates at 25°C for 72 hours, and EMB plates at 37°C for 24-48 hours.

2.5 Statistical Analysis

Physicochemical and microbiological analysis results during storage were compared statistically. Each trial was conducted in two parallels. Evaluation of the results was made using Minitab Statistics Package Program [17]. Data are calculated as mean and standard error. One-way analysis of variance was applied to the data to determine the differences between the samples, and the Tukey Multiple Comparison Test was used for the significant differences. Significance levels ($P < 0.05$) for statistical differences are shown with letters [18].

3 Results and Discussion

3.1 Determination of Chemical Properties of Fresh and Dried Figs

Drying methods can be evaporated free water from food by drying or dehydration. With this application, it is aimed to slow down or stop the growth of microorganisms or chemical reactions [19]. At the same time, the use of quality raw materials reduces the physical and chemical deterioration that may occur in the final product. For this purpose, analyzes were made to determine the physicochemical properties of fresh and dried fig samples using two different methods, and the results are given in Table 1. The amount of dry matter, which was 28.46% in fresh figs, increased to 82.17% in sun-dried figs and 92.72% in freeze-dried figs. When the dry matter content obtained from dried figs were compared, it was determined that more water was removed in the freeze-drying method. In both drying methods, the moisture content of the dried figs remained below the maximum 26% moisture value specified in the

TSE 541 dried fig standard [10]. This difference is due to the fact that freeze-drying is carried out under controlled conditions and vacuum, and moisture absorption from the outside is prevented. In a similar study, it was reported that the dry matter content of Sarılop figs, which was 27.4% in fresh fruit, increased to 82.70% when dried [20]. In another study, the dry matter content, which was 25.55% at the beginning, increased to 86.43% with drying [21].

Table 1: *Analytical properties of fresh and dried figs*

Analysis	TI	GK	LK
Total solid (%)	28.46 ± 0.86^{c}	82.17 ± 0.84^{b}	92.72 ± 0.10^{a}
Ash (%)	1.00 ± 0.07^{c}	2.84 ± 0.02^{b}	3.81 ± 0.25^{a}
Total titratable acidity (%)	0.23 ± 0.44^{c}	1.20 ± 0.05^{b}	1.26 ± 0.10^{a}
Total Sugar (g kg^{-1} DW)	505.10 ± 3.15^{c}	642.97 ± 4.52^{b}	776.18 ± 0.95^{a}

* TI: Fresh figs, GK: Sun-dried figs, LK: Lyophilized-dried figs
**a,b,c Different letters on same row indicate statistically significant difference ($P < 0.05$)

Ash is the inorganic residue left after the combustion of organic materials and increase with drying of fruits. The ash amount of all samples is expressed on a dry weight (DW) basis in Table 1, which was 1.00% on DW in fresh figs, increased to 2.84% on DW with sun drying and 3.81% on DW with freeze drying. The ash content was higher in freeze-dried figs. This is due to the lower moisture content and therefore less water amount in the sample weight.

The total acidity value generally gives information about the ripening status of the figs. Total titratable acidity of fresh fig fruit was determined as 0.23±0.44% in terms of citric acid. In a study conducted with 9 black and 2 yellow fruited fresh figs, it was reported that the total total titratable acidity was between 0.14% and 0.29% [22]. A high total titratable acidity value is not a desirable parameter, as sourness and quality deterioration will occur in fruits [23]. Total acidity in dried figs was found to be 1.20% and 1.26%. In a study conducted with sun-dried fig varieties, it was reported that the total acidity in the samples varied between 0.75-1.67% and it was 1.01% in the Sarılop cultivar [22].

In fresh figs, the total sugar content was determined as 505.10 g kg^{-1} DW. Similarly, in a study conducted with Sarılop figs, it was stated that the total sugar amount was 230.01 g kg^{-1} DW [24]. As the water content of the dried figs with two different methods decreases, the volume decreases and the amount of sugar per unit increases. The amount of sugar in sun-dried figs was 642.97 g kg^{-1} DW, and 776.18 g kg^{-1} DW by freeze drying. This difference is due to the removal of more water in the freeze-drying method. It has been reported that the amount of sugar in sarılop figs dried with traditional methods is 291.35 g kg^{-1} DW [24]. In another study, the total sugar content in fresh, sun-dried and oven-dried figs was determined as 56.36, 229.73, 418.85 g kg^{-1}, respectively [25].

3.2 Color Analysis

Color L (brightness), a (+red,- green) and b (+yellow, - blue) values of sliced fig samples (fresh, directly packaged sun dried, directly packaged lyophilized dried, sun dried packaged under nitrogen, lyophilized dried packaged under nitrogen) were measured before storage (0. month), after 3 and 6 months of storage. After the measurement of these values, the chroma value and Hue angle are calculated and the results are given in Table 2. While the results were similar to the L and a values obtained in fresh figs in the freeze drying method, a decrease was observed in the L and a values with sun drying. It was observed that the b value decreased in both drying methods compared to fresh figs. The difference

between these values was found to be statistically significant. Similar to our study, the a and b values of dried figs changed depending on the storage temperature and duration, and these values decreased significantly, especially at the end of the 9-month storage period [26]. Kelebek et al. [24] in their study, when the yellow fig variety was examined, they found that drying in the sun caused a decrease in the yellow color and stated that there was a sharp decrease in the brightness value. It has been reported that the L* value is 63.4 in the color measurements made on the shells of fresh Sarılop figs, and it decreases to 59.4 when dried [20]. In another study, it was reported that the initial L value was 34.70 in the color measurement of dried figs from the peel [26]. This difference is thought to be due to the fact that the color measurements are made on the inner surface of the figs by slicing.

Table 2: *Color changes in dried figs during storage*

	Months	TI	GKD	GKN	LKD	LKN
L value	**0**	51.41±0.93^{b}	47.22±1.46^{c}		52.39±1.73^{a}	
	3		41.41±0.48^{d}	42.24±0.24^{c}	44.65±0.38^{b}	46.63±0.43^{a}
	6		40.17±1.41^{c}	36.65±1.39^{d}	49.92±0.94^{b}	50.60±1.81^{a}
a value	**0**	9.00±0.57^{b}	6.28±0.28^{c}		10.72±1.19^{a}	
	3		5.63±0.30^{d}	5.91±0.48^{c}	10.95±0.96^{a}	10.81±0.82^{b}
	6		5.65±0.24^{c}	5.40±0.29^{d}	6.37±0.79^{b}	7.39±0.50^{a}
b value	**0**	14.85±0.53^{a}	12.67±2.29^{b}		11.78±0.42^{c}	
	3		6.20±0.48^{d}	11.78±0.42^{a}	7.30±0.23^{c}	8.61±0.43^{b}
	6		7.97±0.50^{c}	7.06±0.58^{d}	12.86±0.54^{a}	10.14±1.04^{b}
Chroma	**0**	17.36^{a}	14.14^{c}		15.93^{b}	
	3		8.38^{c}	13.18^{b}	13.16^{b}	13.82^{a}
	6		9.77^{c}	8.89^{d}	14.35^{a}	12.55^{b}
Hue angle	**0**	58.78^{b}	63.63^{a}		47.70^{c}	
	3		47.76^{b}	63.36^{a}	33.69^{d}	38.54^{c}
	6		54.67^{b}	52.59^{d}	63.65^{a}	53.92^{c}

* TI: fresh figs, GKD: sun-dried figs directly packed, GKN: sun-dried figs packed under nitrogen, LKD: lyophilized-dried figs directly packed, LKN: lyophilized-dried figs packed under nitrogen
**a,b,c,d Different letters on same row indicate statistically significant difference (P <0.05)

After 3 and 6 months storage at room conditions, there was a decrease in brightness, which is the L value, but it was determined that dried figs packaged under nitrogen were better preserved. Likewise, it was determined that packaging under nitrogen was more effective in maintaining the a and b values. However, at the end of the 6th month, it was observed that the b value increased in freeze-dried fig samples. This increase is explained by the fact that the packaging material causes gas passage over time. It is reported that from the first months of storage, depending on the film permeability, the gas composition in the package comes into balance with the atmospheric gas composition to a great extent [27]. While the C value was 17.36 in fresh figs, it was determined that it was better preserved in freeze-dried figs, although it decreased gradually in sun-dried figs with storage. The difference between color values during storage was significant (P <0.05).

3.3 Changes in Microbiological Properties During Storage

After the figs were dried in the sun or by freeze drying methods, they were packaged directly or under nitrogen gas and stored at room conditions for 6 months. Microbiological changes in dried figs during

storage were followed and evaluated with statistical analyzes (Table 3). Although all dried fig samples comply with legal criteria in terms of moisture content according to TSE 541[10], dry matter amounts were not the same in the samples produced with two drying methods. The number of microorganisms are calculated for per gram of each product and presented as the log of microbial counts. The total number of mesophilic aerobic bacteria at the beginning of storage in sun-dried figs was 5.13±0.07 log cfu g^{-1}, and 6.57±0.20 log cfu g^{-1} in lyophilized figs. Villalobo et al. [28] found that the total number of mesophilic bacteria in sun-dried figs was 5.2 log cfu g^{-1}. It was observed that the number of mesophilic aerobic bacteria in dried figs decreased during 6 months of storage. This is due to the decrease in water content with drying, thus limiting the growth of microorganisms. In a study conducted with dried figs that were not treated with any chemicals, it was determined that the microbial load decreased with storage [29]. The decrease in microbial load in the samples packed under nitrogen gas during storage was faster than in the directly packed samples. Because nitrogen is an inert gas used as a packaging filler due to its low solubility in water and lipid. It also prolongs the shelf life of foods by preventing rancidity and inhibiting the growth of aerobic organisms [30].

Table 3. *Microbiological changes (log cfu g^{-1}) in dried figs during storage*

	Months	GKD	GKN	LKD	LKN
TMAB	**0**	5.13±0.07^{b}		6.57±0.20^{a}	
	1	4.36±0.18^{c}	4.69±0.16^{a}	4.44±0.06^{b}	4.00±0.08^{d}
	2	4.20±0.10^{b}	4.41±0.03^{a}	3.91±0.07^{c}	3.67±0.33^{d}
	4	3.26±0.14^{a}	3.16±0.16^{c}	3.20±0.10^{b}	3.06±0.14^{d}
	6	3.02±0.03^{b}	2.36±0.06^{d}	3.10±0.10^{a}	2.92±0.16^{c}
Yeast and mold	**0**	5.69±0.18^{a}		5.57±0.34^{b}	
	1	4.01±0.14^{c}	3.68±0.12^{d}	5.36±0.04^{a}	5.10±0.10^{b}
	2	3.32±0.02^{d}	3.42±0.03^{c}	4.04±0.02^{b}	4.10±0.10^{a}
	4	3.22±0.14^{c}	2.87±0.13^{d}	3.69±0.23^{b}	3.78±0.04^{a}
	6	2.74±0.13^{a}	2.20±0.10^{d}	2.48±0.00^{b}	2.39±0.06^{c}
Total coliform	**0**	3.76±0.06^{b}		4.32±0.02^{a}	
	1	3.61±0.01^{a}	3.62±0.16^{a}	3.52±0.11^{b}	3.47±0.09^{c}
	2	3.20±0.10^{c}	3.29±0.02^{a}	2.64±0.11^{d}	3.26±0.15^{b}
	4	2.09±0.05^{c}	2.06±0.06^{d}	2.52±0.04^{b}	2.56±0.06^{a}
	6	1.92±0.05^{c}	1.67±0.03^{d}	2.20±0.20^{a}	2.10±0.10^{b}

* GKD: Sun-dried figs directly packed, GKN: Sun-dried figs packed under nitrogen, LKD: Lyophilized-dried figs directly packed, LKN: Lyophilized-dried figs packed under nitrogen
** TMAB: Total mesophilic aerobic bacteria
***a,b,c,d Different letters on same row indicate statistically significant difference (P <0.05)

In this study, the total number of yeast and molds in sun-dried figs was determined as 5.69±0.18 log cfu g^{-1}, and 5.57±0.34 log cfu g^{-1} in freeze-dried figs. Villalobos et al. [28] found the total number of mold and yeast in sun-dried figs to be 4.6 log cfu g^{-1}; Akbal and Vural [31] determined it as 3.00 log cfu g^{-1}. The fact that our values are higher indicates that there is contamination from the raw material or in the next stages. Yeast and mold can be transmitted to dried fruits during planting, growth, ripening, processing, drying, storage and transportation [31]. During 6 months of storage, the number of yeast and mold decreases, and a more effective preservation is provided in figs packed under nitrogen gas. The yeast amount values of dried figs, which were determined as 2.97 log cfu g^{-1} at the beginning of storage, changed between 2.67-2.99 log cfu g^{-1} at the end of the storage period [26].

The number of coliform bacteria was found 3.76±0.06 log cfu g^{-1} in sun-dried figs and 4.32±0.02 log cfu g^{-1} in freeze-dried figs. Villalobos et al. [28] in their study evaluating different drying systems, found that the total number of coliforms in sun-dried figs was 2.3 and 2.5 log cfu g^{-1}. It was observed that the total number of coliforms in dried figs decreased during storage.

4 Conclusions

In this study, figs, which are an important commercial product and mostly traditionally sun-dried whole, were sliced and dried. Thus, it is aimed to produce dried figs, which dry in a shorter time, have a more crispy and different structure. With the controlled freeze-drying method, moisture absorption from the outside is prevented, thus limiting the activities of microorganisms. Today, figs dried whole with the traditional method need to be stored at lower temperatures than room temperatures. The increase in storage and marketing temperature in figs preserved by this method rapidly reduces the shelf life of the product. In this study, microbiological changes were observed during both drying methods and storage under room conditions for 6 months by packing directly or under nitrogen gas. According to the results obtained, it has been determined that the figs packed with sealed packages can be stored at room temperature by preventing moisture absorption from the outside. In this way, it is foreseen that the energy costs spent for keeping the warehouses cool can be reduced. In addition, by freeze drying method, dried figs were obtained closer to fresh figs in color and form of the product compared to the traditional method. This supported that the sensory properties of freeze-dried figs are closer to fresh figs.

5 Declarations

5.1 Study Limitations

None.

5.2 Funding source

None.

5.3 Competing Interests

There is no conflict of interest in this study.

5.4 Authors' Contributions

Ayşe Özge YAVUZ and **Harun BÜYÜK** provided laboratory studies, follow-up of analyzes and evaluation of results. **Tuba BÜYÜKSIRIT BEDİR** and **Hakan KULEAŞAN** provided the planning, execution and writing of the research. The authors have read and approved the final version of the article.

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