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Comparative analysis of solvent extraction of rice bran oil from various sources

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ABSTRACT

This study investigated oil extraction from rice bran a by-product of rice gotten from different sources (Afikpo, Abakaliki, and Emene). The oil was extracted from different particle sizes (150 µm, 300 µm, and 420 µm) of the rice bran using three different solvents namely chloroform, petroleum ether, and n-hexane at constant time of 120 minutes via soxhlet extractor. The physiochemical properties of the extracted oil were boiling point, the saponification values and refractive index were 77 °C, 185.130, and 1.334, respectively. Also the acid value, surface tension, iodine value, and relative density were found to 15.040 g, 6.966×10^2 N/M, 99.480, and 0.779, respectively. The obtained result based on source revealed that the maximum oil yield of 35.05 g was achieved from Abakaliki rice bran using chloroform solvent and particle size of 420 µm, whereas Emene and Afikpo gave 32.62 g and 14.18 g of oil, respectively from same solvent and particle size. Again, the highest volume of oil obtained in terms of solvent used were chloroform, petroleum ether, and n-hexane, in descending order. The physicochemical properties investigated, showed that the extracted rice bran oil (RBO) from the above three sources in Nigeria confirms RBO to be of good quality and can be utilized in many food industries after refining in form of additives/or industrial purposes as well as in generation of energy.

Keywords: Abakaliki, rice bran oil, solvent extraction, comparative analysis, Nigeria

INTRODUCTION

Rice is one of the cereals that is globally consume. It contains high percentage of carbohydrates, minerals (calcium and iron) and vitamins (Rathna Priya et al., 2019). Rice is a tropical plant and described as a monocotyledonous plant of a plant kingdom. It is grown in the evergreen rain forest belt, low humidity, and adequate water supply. The life cycle of rice is usually completed within the range of 100 to 210 days, with the mold falling between 110 to 150 days. It undergoes three stages of vegetative, reproductive and ripening within this period. When rice is milled in the industry, the outer hard coat is removed. This outer covering is referred to as rice bran. Go et al. (2020) and Van Hoed et al. (2006) reported 8.00% by-product (bran) yield of a rice milling process. Rice bran oil (RBO), a special and important vegetable oil, is extracted from rice bran. According to Punia et al. (2021), the antioxidative, antimicrobial, anti-inflammatory, anti-cancerous, and antidiabetic properties makes it a very useful substrate in both the application in food and non-food industries. The use of suitable volatile solvents in extracting oil from oil inherent materials is a very useful technique as it produces a higher yield compared to the mechanical methods and it does not also denature the protein content of the residual cake.

Previous studies of recovering crude oils from vegetable by using nonporous membrane resulted to high rejection of color compounds phosphides (Saravanan et al., 2006). The solvent dissolves the oil present in cells of the materials during the solvent extraction process of oil bearing material. The solvent is stripped off the miscella and recycled. The marc (cake from the material after the oil has been extracted) contains very small quantity of oil and considerable amount of solvent, which can be recovered in vapor form using dryer and then condensed for recycling. The solvent loss during this process is negligible. During rice processing, some of the byproducts produced include broken rice, husks, germs, and bran, which are discarded as waste or used as animal feeds. It contains about 65.00% of the nutrients of the whole rice grain and it is one of the eye-catching by products of rice with 8.00%-9.00% rice weight (Begum et al., 2015; Limtrakul et al., 2019). Asian countries produce and consume rice bran in large quantity and as a result it (rice bran) gained its usefulness as a "healthy oil," in extraction of RBO (Rohman, 2014; Wang et al., 2020, 2022).

Accordingly Lai et al. (2019) and Wang (2019) have shown that RBO treasured by product possessed numerous important qualities such as anti-inflammatory and antioxidant abilities.

Table 1. Physical properties of crude & refined bran oil

Property	Crude rice bran oil	Refined bran oil
Moisture	0.50%-1.00%	0.10%-0.15%
Density 25 °C	0.913-0.920	0.913-0.920
Refractive Index 25 °C	1.4672	1.4672
Iodine value	85-100	95-104
Saponification value	174-187	174-187
Unsaponifiable matter	4.5-5.5	1.8-2.5
Free fatty acids	5.00%-15.00%	0.15%-0.20%
Oryzanol	2.0	1.5-1.8
Tocopherol	0.29-0.15	0.10-0.05
Color (tintomer)	20Y+2.8R	10Y+1.0R

Some of these benefits of RBO are anti- carcinogenic, anti-diabetic, anti-obesity and anti- hypertensive properties. These health benefits of RBO can be traced to the presence of γ -oryzanol, which is an antioxidant mixture of ferulic acid esters of phytosterols (Garofalo et al., 2021; Go et al., 2020), as the main constituents of RBO. As a result of the above properties of RBO, American Heart Association, World Health Organization, and some other international food and health organizations have acknowledged RBO as a "healthy oil," due to its well-proportioned fatty acid content, which comprises of 20.00% of saturated fatty acids (SFAs), 47.00% of monounsaturated fatty acids, 33.00% of polyunsaturated fatty acids (Ghatak & Panchal, 2011). Some of SFAs present are myristic, stearic acid and palmitic, while the unsaturated ones are linolenic acid, oleic acid, and linoleic acid (Godber, 2009; He & Liu, 2019; Lai et al., 2019; Maurya & Kushwaha, 2019). Again, RBO has a smoke point of about 255 °C and is steady at high temperatures. RBO can be described as an outstanding/exceptional oil based on the above qualities for application in food, pharmaceutical, cosmetic, and nutraceutical industries. It can improve the moisturizing activity of the skin and inspire hair growth when used in the cosmetics industry. Also, RBO works as anti -skin aging due to the presence the ferulic acid and esters of γ -oryzanol (Maurya & Kushwaha, 2019; Rohman, 2014). This work centered on comparative study of oil yield from three different solvents through soxhlet extractor, extraction process and the characteristics of RBO by application of three organic solvents. The effects of solvents on the source of the rice bran and the size of the rice bran on the yield of oil and extraction rate was determined and discussed. **Table 1** presents physiochemical properties of oil (Garofalo et al., 2021).

MATERIALS & METHODS

Materials: Sourcing & Preparations of Materials

The rice bran used in this study were collected from three different sources namely: Abakaliki, Afikpo, and Emene. Impurities in the samples were removed by selection and hand picking. The collected samples were size reduced into three sizes, 150 µm, 300 µm, and 450 µm, respectively to increase the surface area and enhancement of effective oil extraction. All reagents used were Analytical grade.

Experimental Procedures

50 g of each sample were weighed from the three different particle sizes (150, 350, and 450 m) for different sources (Abakaliki, Afikpo, and Emene), respectively. The weighed samples were placed into a porous thimble and inserted inside the soxhlet extractor fitted with reflux condenser. The extractor was mounted on a round bottom flask containing 150 ml of each solvent at a time. The entire set up was placed on a heating mantle.

As the extraction operation progresses, the vaporized solvents were refluxed back into the flask. This continued until a greenish colour called miscella is observed. This procedure was repeated for all the particles, and sources with all the solvents. Finally, the remaining traces of solvents entrapped in the oil thus extracted removed via bench distillation unit. The percentage yield of oil obtained were calculated by Onukwuli et al. (2016):

$$Percentage\ yield = \frac{Weight\ of\ oil\ produced}{Weight\ of\ bran} \times \frac{100}{1}.$$

Characterization of Rice Bran Oil

Analysis of oil is carried out to identify the constituents and control its quality and purity. This is necessary in an industry and requires the determination of physical and chemical properties like density, viscosity, iodine value, acid value, moisture content, boiling point, Refractive index e t c were determined according to Onukwuli et al. (2016). A brief analysis of these parameters are, as follows:

1. **Boiling point:** Liquid boils when the pressure is equal to the atmospheric pressure. The temperature at this point is referred to as the boiling point. It helps in determining the purity and class of the oil. It is therefore a very important parameter in quality control.
2. **Refractive index:** This is the attribute of oil that measures the angles a beam of light is bent as it passes via a thin film of melted fat or oil. This is achieved using a refractometer at the temperature of 20 °C to 50 °C during which most oils are liquid. The higher the viscosity of the oil, the greater the angle of deviation of the oil. Temperature greatly affects refractive index measurement, therefore high precision is required in temperature control to avoid having significant variation. This is to ensure that a noticeable refractive index change does not occur (Stubbing et al., 2020).
3. **Acid value:** This is the amount of free fatty acid contained in fat or oil. Its increase decreases edibility of the oil. The formular for calculating acid value is, as follows:

$$Acid\ value = 5.61 \times \frac{Titre\ value}{Weight\ of\ sample}.$$

4. **Moisture content:** This refers to the quantity of water in percentage contained in the oil. It is estimated by calculating the loss in mass when the oil is heated to a temperature of 103 °C under the specified operating conditions of temperature and pressure:

$$Percentage\ moisture\ content = \frac{W_1 - W_2}{W_1} \times 100,$$

where w_1 and w_2 are the weight of oil before and after drying, respectively.

Table 2. Oil yield obtained from different sources using 50 g rice bran each at t=120 minutes

Solvent (150 ml)	Chloroform			N-hexane			Petroleum ether		
Sieve size (µm)	**150**	**300**	**450**	**150**	**300**	**450**	**150**	**300**	**450**
Abakaliki									
Oil obtained (%)	38.74	28.58	2.78 (70.10)	8.86	5.20	0.92 (14.98)	22.50	4.26	0.92 (27.68)
Solvent recovered (ml)	110	105	100	80	75	70	105	100	95
Rate of extraction (mins)	0.161	0.119	0.012	0.037	0.022	0.004	0.094	0.018	0.004
Afikpo									
Oil obtained (%)	13.72	11.18	2.78 (28.36)	8.94	4.80	4.02 (17.76)	12.50	5.72	3.50 (21.72)
Solvent recovered (ml)	75	85	95	60	60	55	90	95	100
Rate of extraction (mins)	0.057	0.047	0.014	0.037	0.020	0.012	0.052	0.024	0.015
Emene									
Oil obtained (%)	45.30	16.48	3.46 (65.24)	9.48	7.40	5.01(21.89)	8.70	8.14	7.70 (24.54)
Solvent recovered (ml)	115	105	100	85	75	70	90	95	100
Rate of extraction (mins)	0.032	0.034	0.036	0.035	0.031	0.002	0.036	0.034	0.032

5. **Specific gravity:** Relative density of oil is the weight of a given volume of oil per weight of an equal volume of water at the same temperature. Density or specific gravity is measured using a density bottle.

$$Specific\ gravity = \frac{Weight\ oil}{Weight\ of\ equal\ volume\ of\ water}.$$

6. **Iodine value:** This is the amount of iodine absorbed by 100 g of oil. Iodine value measures the proportion of unsaturated acids present and therefore the measure of drying characteristic of an oil (Onukwuli et al., 2016):

$$Iodine\ value\ (IV)\ (gl_2/100\ g\ oil) = \frac{12.69 \times M(B-V)}{W},$$

where M is molarity of thiosulphate solution, B and V are the volume of thiosulphate in blank and test titration, respectively, and W is the weight oil sample.
7. **Viscosity:** This is a measure of ease by which one layer of a fluid moves past another. Ostwald viscometer and falling ball are used in determining the viscosity of oil.
8. **Saponification value (SV):** This is the amount of potassium hydroxide in milligram needed to saponify one gram of fatty acid resulting from complete hydrolysis of one gram of sample. By-product of the reaction is soap. This is important in characterizing the fat since within biological limit, each oil has a constant fatty acid composition that is:

$$Saponification\ value\ (mgKOH) = \frac{(V_2 - V_1) \times 28.05}{W},$$

where V_2 is volume of 0.5 m HCl to titrate blanks, V_1 is volume of 0.5 m HCl to titrate sample, and W is weight of sample.

RESULTS & DISCUSSION

Effect of Particle Size on oil Yield

The rice sample employed in this study was size reduced to facilitate effective extraction of oil resulting from increased interfacial surface area between the solid (rice bran) and liquid (solvent) as presented in **Table 2**.

Figure 1 shows that the smaller the particle size, the higher the rate of transfer of material and the smaller the distance the solute must diffuse within the solid (Rohani, 2017). This can be attributed to increase in interfacial surface area of the rice bran from 150 µm-450 µm. Again, it is obvious from **Figure 1** and **Table 2** that increase in particle sizes (150 µm-450 µm) decreases the quantity of oil yield. It is equally

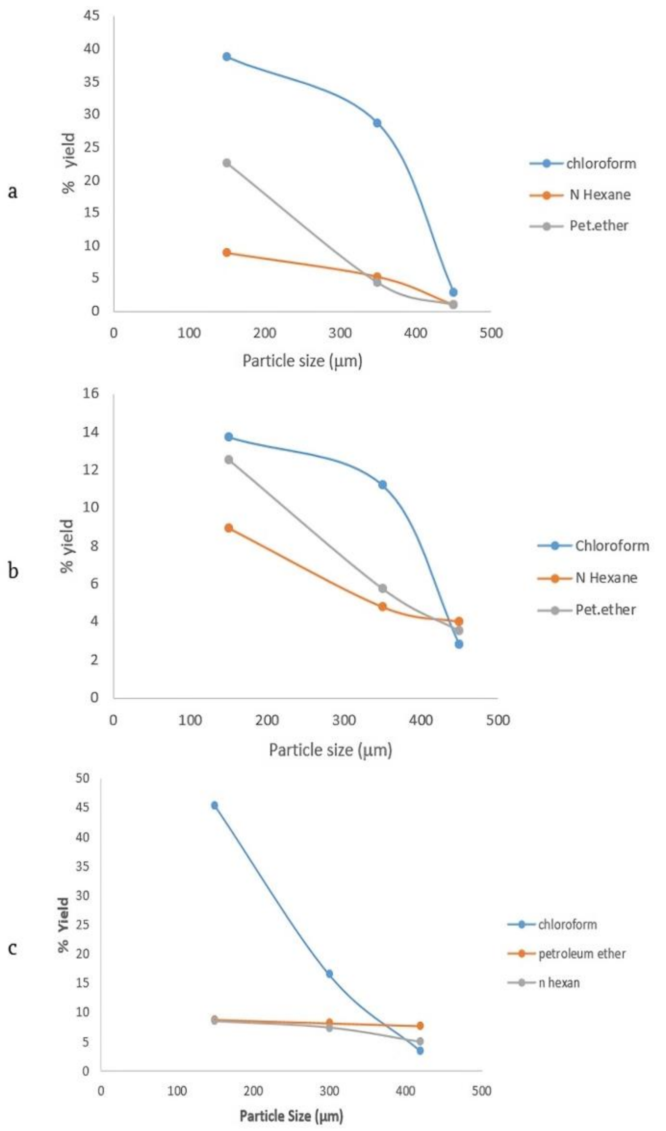

Figure 1. Effect of particles sizes on yield from different sources: Abakaliki (a), Afikpo (b), & Emene (c) (Source: Authors' own elaboration)

observable from same **Figure 1** and **Table 2**, that the highest oil yield of 45.30% was achieved using chloroform and particle size of 150 µm from Emene source while the lowest value of 0.92% was obtained from Abakaliki with petroleum ether and

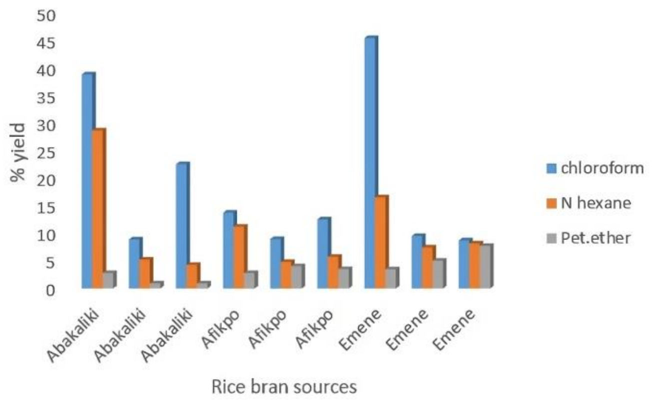

Figure 2. Effect of rice bran source on oil yield (Source: Authors' own elaboration)

particle size of 450 µm. These results agreed with (Abbas Ali et al., 2019; Rusanov et al., 2017).

The rate of leaching as can be seen from **Table 2** was equally faster at smaller particle sizes. This can be as a result of high diffusion rate of solute through the mass of the cell wall thereby achieving equilibrium faster. Furthermore, the shapes of n-hexane and petroleum ether plots appears straight as can be seen in part c in **Figure 1**.

This can be attributed to impediment of solvent circulation due to non-effective use of surface (fine material) making it difficult for the particles to separate from the solvent and drainage of solid residue.

Effect of Rice bran Source on Oil Yield

The comparative analysis of oil yield obtained from the three different sources studied were presented in **Figure 2**. Close inspection of **Figure 2** shows that Emene source produced the highest oil yield of 45.30% with chloroform, Abakaliki and Afikpo gave 38.74% and 13.72%, respectively with the same solvent (chloroform) (Chatha et al., 2011). This can be attributed to solubility of materials (oil) being extracted with the solvent. Cumulatively, it is observable from **Table 2** that Abakaliki source produced the maximum achievable oil yield from the three sources studied with the total value of 70.10%, as shown in the data in bracket on same **Table 2**. Hence, the yield from the three sources can be represented in descending order as Abakaliki, Emene, and Afikpo. These can be attributed to the fertility and topography/climate of different sources.

Effect of Solvent on Oil Yield

Out of the three solvents used in this study, chloroform gave the utmost oil yield of 45.30% from 50 g rice bran source each from Emene, 38.74% from Abakaliki, and 13.72% from Afikpo, as shown in **Figure 3** and **Table 2** with a particle size of 150 µm, respectively. This agrees with the work of Javed et al. (2014), Nwabanne et al. (2014), and Ajali et al. (2022). This can be as a result of its low viscosity that helps it to circulate freely during the operation. Also, the climatic location of the source can equally contribute to the high achieved. Summation of all the values of oil yield obtained from the three different particles sizes used showed that chloroform solvent gave the maximum oil yield of 70.10% from Abakaliki source followed by Emene with 65.24% and Afikpo 28.36%, respectively (**Table 2**). Again from **Table 2**, the quantity of solvent used in producing the oil was minimal compared to the quantity of solvent recovered from the three solvents.

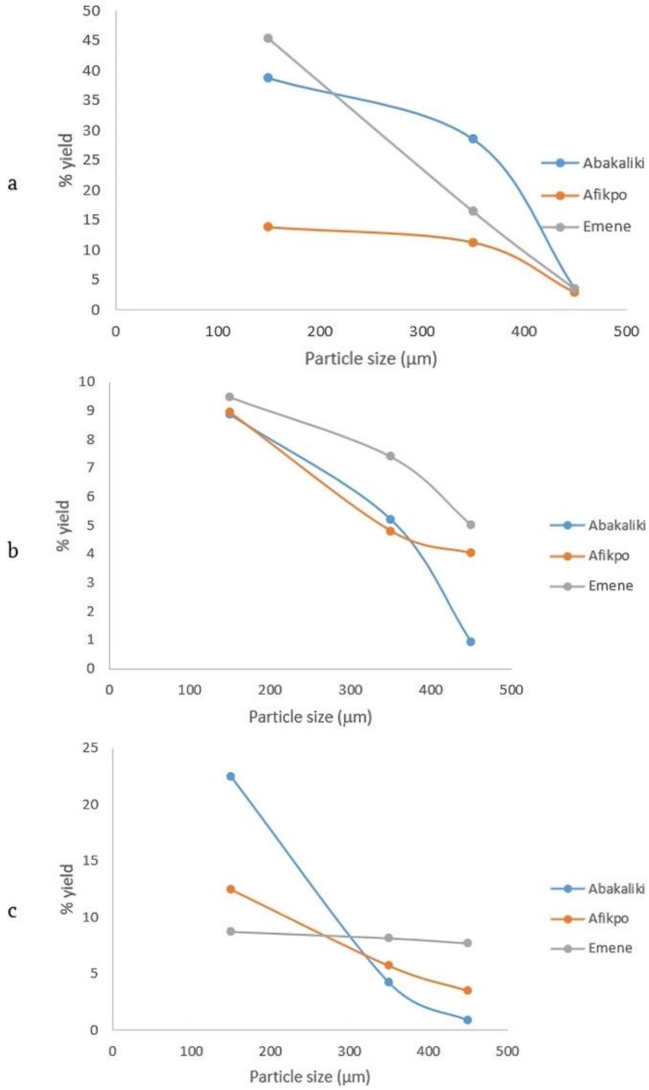

Figure 3. Effect of yield on different solvents: chloroform (a), n-hexane (b), & petroleum ether (c) (Source: Authors' own elaboration)

Further analysis of **Table 2** also indicates that collective volume of oil yield from petroleum ether in all the three sources far outnumbered that of n-hexane. This can be as a result of increase in the concentration of solute during the extraction process, which causes gradual decrease in the rate of extraction due to reduction in concentration gradient as well as the solution becoming more viscous in part c in **Figure 3**. Also, oil yield from the three solvents can be represented in an ascending order as n-hexane, petroleum ether, and chloroform.

Rate of Leaching on Yield

The rate of extraction of rice bran, as can be seen from **Table 2**, shows that equilibrium was achieved faster especially in smaller particles sizes of 150 µm during the extraction processes. This is as a result of high interfacial area of the particles creating enabling environments for the solvents to diffuse easily through the solid materials. Also, the solubility

Table 3. Physiochemical properties of oil produced

Properties	Values
Physical properties	
Refractive index	1.334
Specific gravity	0.779
Boiling point	77 °C
Surface tension	9.966×10^{2} N/m
Chemical properties	
Saponification value	185.130 mgKOH
Acid value	15.040 g
Iodine value	99.480 gI_2/100g

of the rice bran being extracted helped to increase the temperature resulting in higher rate of extraction.

Rate of extraction was improved as diffusion coefficient of process increases with rise in temperature thereby increasing the yield. Furthermore, as the particle sizes increases from 350 µm-450 µm the rate of extraction is progressively reduced due to high viscosity and decrease in concentration gradient. This is exhibited by materials with low interfacial areas as seen on the yield of the bigger particles sizes in **Table 2**.

Physiochemical Properties of Oil

Physiochemical properties of extracted oil were analyzed to determine the quality of the oil and the results are presented in **Table 3**. Also, physiochemical properties of oil obtained in this work is same irrespective of source and solvent used. Refractive index of an oil is defined as the ratio of speed of light at a defined wavelength to its speed in the oil/fat. This value varies with wavelength and temperature, the degree and type of unsaturation, the type of substitutions of component fatty acids and with accompanying substances. It is widely used in quality control to check for the purity of materials. The relative density of the oil was 0.779. The result obtained indicated that oils is less dense than water and could be beneficial in cosmetic industry as it will make the oil flow and readily spread on the skin. Acid value gives an indication of the quality of fatty acids in oil. Acid value of 15.040 g is low and within the acceptable range. It shows that oil will be steady for a long period of time and defends against rancidity and peroxidation. This could be attributed to the presence of natural antioxidants in the oil. Also, it is used as a pointer for edibility of an oil and suitability for use in paint and soap industries (Aremu et al., 2015).

SV of the oil is 185.130. It is a representation of fatty acid chain length or average molecular mass and necessary in determining the quantity of alkali required in converting a certain amount of oil into soap, thereby detecting adulterated oil. In line with Otunola et al. (2009) and Parthasarathy et al. (2014), SV of RBO is low compared to that of other oils. High SV leads to low fatty acid average length and mean molecular weight of triglycerides becomes lighter agrees with Atinadu and Bedemo (2011). RBO is plant based oil, edible and can be used in cooking and formulation of other food products. According to Zahir et al. (2017), since most oils used for food formulations, frying or cooking are from plants. Iodine value shows the extent to which unsaturated acids are present and gives an idea of the drying character of oil. It also helps to check adulteration. The iodine value for RBO is 99.480 gl2/100g signifies that the oil is edible and in agreement with Onukwuli et al. (2016). The oil is reactive, less stable, softer and susceptible to oxidation and rancidification. The boiling point of 77 °C is an indication that the oil is lighter than water and boils at a temperature less than that of water.

CONCLUSIONS

In conclusion, the world production of rice increases progressively over the years as the demand for food and bran oil rises. The essential fatty acids present in bran oil cannot be manufactured by human body and must be obtained from diets (example bran oil) that contains these unsaturated fatty acids. Furthermore, the high oil yield achieved in this study from Abakaliki and Emene sources can be attributed to several factors like the geographical area of the source and increased interfacial surface area in addition with the nature of solvent used. Hence, chloroform is performs better compared to the other solvents.

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Ethical statement: The authors stated that the study did not require ethics committee approval since no live subjects were used during the study.

Data sharing statement: Data supporting the findings and conclusions are available upon request from corresponding author.

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