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Experimental study of preparing the $CoFe_2O_4$ magnetic nanofluid and measuring thermal-fluid characteristics of the stabilized magnetocaloric nanofluid

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ABSTRACT

The purpose of this study was to examine the rheological features of $CoFe_2O_4$ superparamagnetic nanoparticles dispersed in water-ethylene glycol (EG) coolant as the basis fluid. The experiments are carried out at temperatures between 10 and 50 degrees Celsius, with five mass fraction concentrations of magnetocaloric nanofluid as well as different shear rates. The solvothermal-produced cobalt ferrite metallic compounds are disseminated in EG-water (50:50) coolant. Evaluation of functional groups and organic compounds, the crystal structure of spinel ferrite, the size and morphology of nanoparticles, and the specific surface area, respectively, were carried out. For the developed magnetocaloric nanofluid, shear rate variation illustrates the non-Newtonian behavior of Bingham plastic. The results show that increasing the mass concentration of nanoparticles from 0.05 % to 0.8 % results in about 80 % increase in viscosity at 10 °C. Additionally, thermal conductivity has increased to a maximum of 9.4 % at 50 °C and is improved by increasing temperature.

1. Introduction

In the last century, the issue of energy efficiency has become particularly important. Therefore, scientists are always trying to reduce energy consumption, optimize devices and increase the efficiency of all industries [1]. Various numerical and experimental methods have been proposed to optimize the processes. One of the most important numerical methods is machine learning and artificial neural network. The use of these methods leads to obtaining an optimal system [2–4]. Furthermore, some of the experimental effective methods to increase system efficiency in all heating systems are the use of nanofluids (NFs), magnetic fields, and ultrasonic waves [5–7]. Nanofluids generally consist of a combination of nanoscale particles with one or more liquids. The use of these fine particles to the fluid can enhance its thermal characteristics and boost heat transfer [8,9]. The relation between effectiveness and viscosity/thermal conductivity of nanofluids is important to understand the heat transfer performance and efficiency of these fluids. The thermophysical properties of nanofluids, such as thermal conductivity, viscosity, density, specific heat, and enthalpy, play a crucial role in determining their behavior and heat transfer capabilities. The addition of nanoparticles to base fluids can significantly increase the thermal conductivity of nanofluids, with some studies reporting up to five times enhancement. This enhanced thermal conductivity helps in improving the heat transfer efficiency of the system. On the other hand, the viscosity of nanofluids can vary with temperature and volume fraction. Generally, the viscosity decreases with increasing temperature and increases with increasing volume fraction of nanoparticles. The viscosity of nanofluids affects the flow behavior and pumping power required in the system. It is important to study and understand these thermophysical properties of nanofluids to optimize their composition and concentration of nanoparticles. By doing so, researchers can enhance the thermal

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Nomenclature

EG	Ethylene glycol
k	Thermal Conductivity (W/m.K)
NF	Nanofluid
BF	Basefluid
NP	Nonoparticle
FTIR	Fourier-transform infrared spectroscopy
XRD	X-Ray diffraction analysis
SEM	Scanning electron microscopy
BET	Brunauer, Emmett and Teller
BJH	Barrett Joyner Halenda
RTC	Relative thermal conductivity
CMC	Carboxymethyl cellulose
W	Watt
g	Gram
S	Second
m	Meter
K	Kelvin
Co	Cobalt
O	Oxygen
Fe	Ferrum
Greek Symbols	
φ	Mass Fraction (%)

conductivity and heat transfer capabilities of nanofluids, leading to increased system efficiency. In addition, one of the most widely used and useful particles that can be used in different fluids is nanoparticles with magnetic properties [10,11]. Magnetic nanofluids have engrossed in consideration due to their magnetic field tunable rheological and thermal conductivity characteristics. The field-induced aggregation of magnetic nanoparticles act as low resistance passage thereby enhancing thermal transport significantly [12]. Some studies verify that superparamagnetic nanoparticles display notable improvement in thermal conductivity. In the presence of a magnetic field in spite of negligible viscosity increasing, thermal conductivity improvement is important for successful thermal control of electronic devices [13].

The most important factor in determining the effectiveness of these particles is determining the viscosity and thermal conductivity of NFs. The use of some base fluids such as ethylene glycol, water, and ethanol in the preparation of nanofluids is also common [14,15]. Therefore, some previous researches have been conducted to experimentally measure the thermal conductivity and viscosity of different NFs.

A brand-new equation was put forth by Parsian and Akbari [16] to estimate the thermal conductivity of Al_2O_3-Cu/EG NFs. When the findings were compared, it was discovered that using nanoparticles increases the nanofluid's thermal conductivity in comparison to the base fluid (BF). Shayan and Akbari [17] evaluated changes in the MWCNTs-SiO_2/water-EG hybrid NF thermal conductivity. Their results demonstrated that after nanofluid stability, the nanofluid thermal conductivity's value is much better than the BF, and the changes in temperature and volume fraction are directly related to the thermal conductivity value. Kakavandi and Akbari [18] analyzed the MWCNTs-SiC/water-EG nanofluid thermal conductivity. By presenting a new relationship, they stated that the coefficient of hybrid NFs thermal conductivity increases compared to the BF, and this value also enhances with increasing temperature and volume fraction. In a numerical-empirical research, Hemmat et al. [19] evaluated the thermal conductivity behavior of the $Mg(OH)_2$-Ethylene Glycol NF. Their outcomes showed that there is an appropriate correlation between the proposed empirical and numerical relationships. Also they found that using the ANN method is more accurate in predicting thermal conductivity. Hemmat et al. [20] measured the CuO/water-EG NF thermal conductivity in an empirical investigation. By changing the concentration of nanofluid at different temperatures, they concluded that by enhancing the volume fraction of nanofluid and temperature, the amount of thermal conductivity increases. In order to enhance the thermal conductivity and heat transmission rate within a collector, Arjunan et al. [21] evaluated the influence of utilizing a hybrid NF made of zinc-ferrite/water. The outcomes demonstrated that the use of zinc-ferrite composite nanoparticles further leads to the heat transfer coefficient improvement compared to pure ferrite. Tahir et al. [22] evaluated the thermal properties of two-phase ferromagnetic NFs hybridized to $NiZnFe_2O_4$ and $MnZnFe_2O_4$. Their findings demonstrated that using this hybrid NF performs better in heat transfer than using a straightforward two-phase flow. The impact of a magnetic field and a Fe_3O_4/water NF with variable thermal conductivity on the heat transmission rate was examined by Lahmar et al. [23]. The outcomes demonstrated that the nanoparticles utilization substantially enhances the heat transfer. MgO/EG and Fe/EG, two NFs, were tested for thermal conductivity by Alirezaie et al. [24]. Their findings demonstrated that the use of NF with iron particles compared to magnesium oxide particles can increase the amount of thermal conductivity more under the same conditions. The impact of using magnetic nanofluids in high-power transformers was examined by Lucian et al. [25]. Their findings demonstrated that adding Fe_3O_4 magnetic nanoparticles can improve the BF's thermal conductivity. It was also found that the magnetic field affects magnetic nanoparticles and their physical properties and creates magnetic convection that can increase heat transfer. Muhammad and Nadeem [26] evaluated Mn-$ZnFe_2O_4$, Ni-$ZnFe_2O_4$, and Fe_2O_4 ferrite nanoparticles in ferromagnetic nanofluids. Their outcomes demonstrated that the use of ferrite NPs has a crucial role on the control of thermal boundary layers and these particles utilization can increase the convection heat transfer performance.

The thermal conductivity of $MnFe_2O_4$ nanofluids in the existence of a homogeneous magnetic field was examined by Amani et al. [27]. Their findings demonstrate that with enhancing temperature and concentration of nanofluid, the thermal conductivity enhances. It was also found that a uniform magnetic field employment enhances the nanofluids' thermal conductivity. Sarbolookzadeh et al. [28] analyzed the impacts of temperature and volume fraction of MWCNTs–Fe_3O_4/EG NF on thermal conductivity. Their findings demonstrated that as temperature and concentration enhances, thermal conductivity also enhances. A Fe_3O_4-Diamond/EG-Water hybrid NF's thermal conductivity and viscosity were evaluated by Sundar et al. [29]. Their outcomes demonstrated that nanoparticles utilization leads to an increment in the base fluid's thermal conductivity. It was also found that when utilizing a combined nanofluid of water and ethylene glycol, the higher concentration of water fluid in the composition caused to the higher thermal conductivity.

The impact of magnetic field employment on the viscosity of a Fe_3O_4-water magnetic NF was evaluated by Wang et al. [30]. Their findings demonstrated that the viscosity of Fe_3O_4 NF reduces with rising temperature and rises with both magnetic induction and solid volume fraction. The relationship between temperature and nanofluid content and viscosity was examined by Soltani and Akbari [31]. Their findings illustrated that the nanofluid's viscosity enhances with rising volume percentage and falls by rising temperature. Shylaja et al. [32] analyzed the thermal conductivity of Fe_2O_3-Propylene Glycol nanofluids. Their findings demonstrated that the nanofluid utilization with a concentration of 2 % led to a 21 % thermal conductivity improvement at ambient temperature. Sundar et al. [33] evaluated the thermal conductivity and viscosity of nanofluids in order to use Fe_3O_4 nanoparticles for thermal applications. The findings demonstrated that with enhancing the

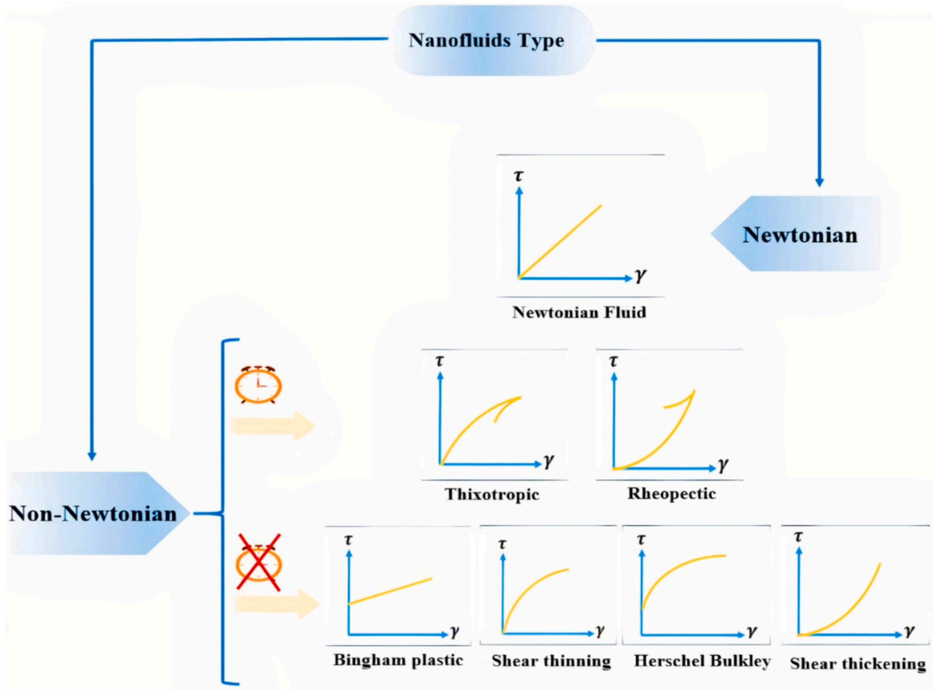

Fig. 1. Types of nanofluids behavior.

Table 1
Specification of materials in cobalt ferrite colloidal.

Compound name	Chemical formula	Molar mass (g/mol)
Sodium acetate anhydrous	CH_3COONa	82.03
Cobalt (II) chloride dihydrate	$CoCl_2{\cdot}6H_2O$	129.84
Ethylene glycol	$C_2H_6O_2$	82.03
Iron(III) chloride hexahydrate	$FeCl_3{\cdot}6H_2O$	270.33

concentration of nanoparticles and temperature, the amount of thermal conductivity increases. They also proposed an equation with very high accuracy to predict the amount of thermal conductivity. The viscosity and thermal conductivity of Fe_2O_3 NFs were assessed by Colla et al. [34]. Their results revealed that this fluid is a non-Newtonian fluid and the amount of thermal conductivity enhances with rising concentration of NF and temperature.

So far, many researches are done to investigate the substantial role and thermal behavior of various nanofluids with different applications [35–37]. Additionally, research has been done on the use of Fe_3O_4 particulates in different fluids. $CoFe_2O_4$ colloidal NPs cluster's thermal conductivity and viscosity, however, have not been assessed. This innovative study investigates the synthesis and application of superparamagnetic nanoparticles in order to create coolant fluid and ascertain the rheological characteristics of the resultant nanofluid. The difference between Newtonian and non-Newtonian fluids is that in Newtonian fluids the relationship between stress and strain rate is linear, direct, and time-dependent, but in non-Newtonian fluids, this relationship is not linear. Fig. 1 depicts the differences between Newtonian and non-Newtonian fluids. In addition, based on Fig. 1, in order to ascertain the sort of behavior of NFs, viscosity and the shear stress in terms of shear rate are assessed. $CoFe_2O_4$ colloidal nanoparticles have unique properties [38] which using them as a magnetocaloric nanofluid can improve the efficiency of all thermal cycles.

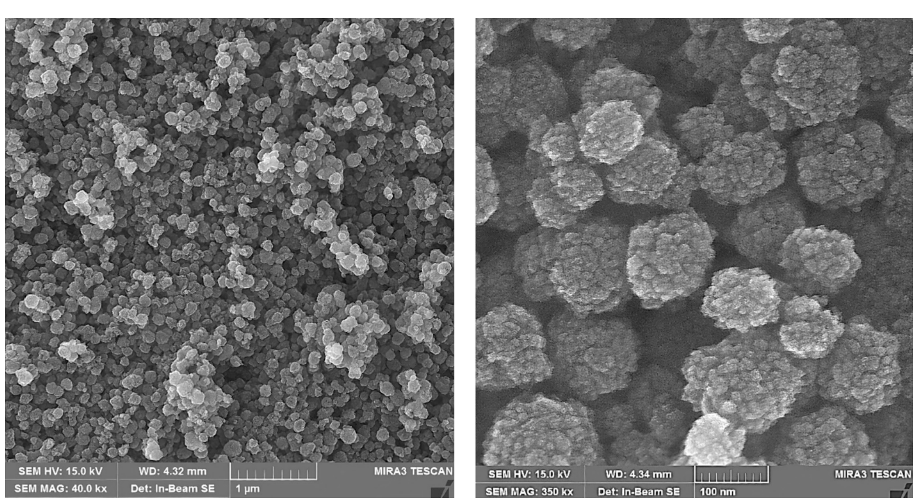

Fig. 2. SEM images of cobalt ferrite metallic compounds.

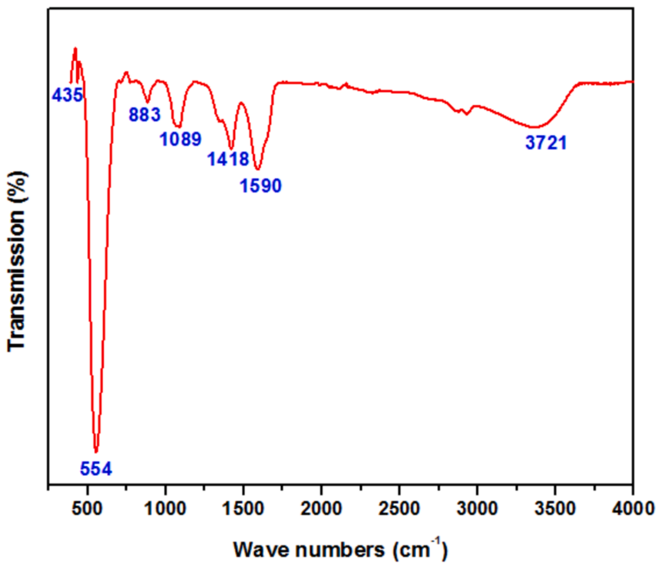

Fig. 3. FTIR spectra of cobalt ferrite samples [38].

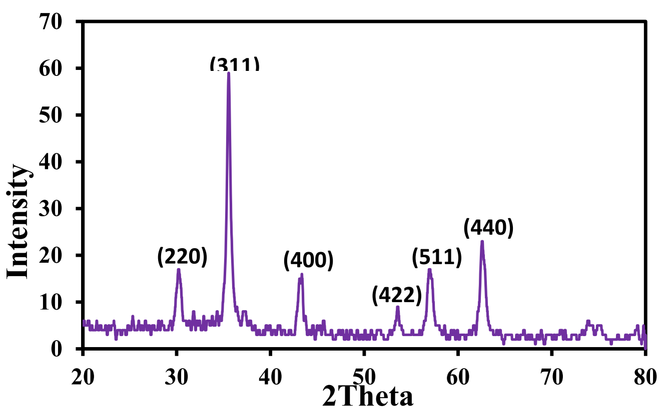

Fig. 4. The XRD test result for $CoFe_2O_4$ nanoparticle.

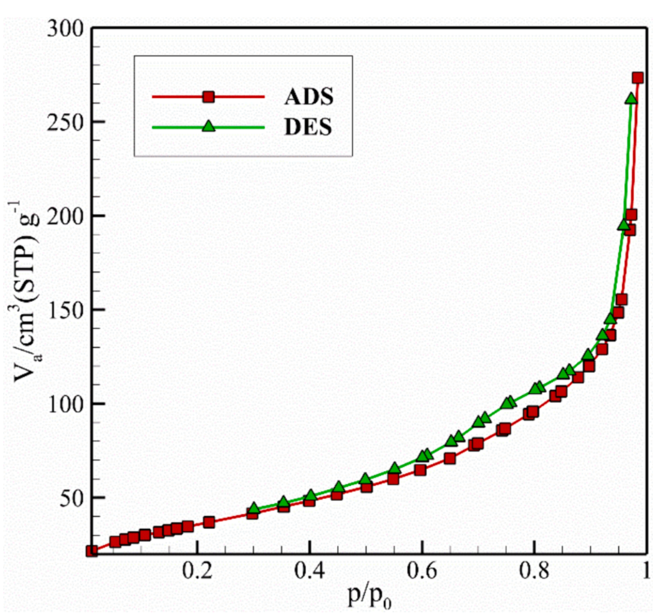

Fig. 5. Adsorption/desorption isotherms for the sample.

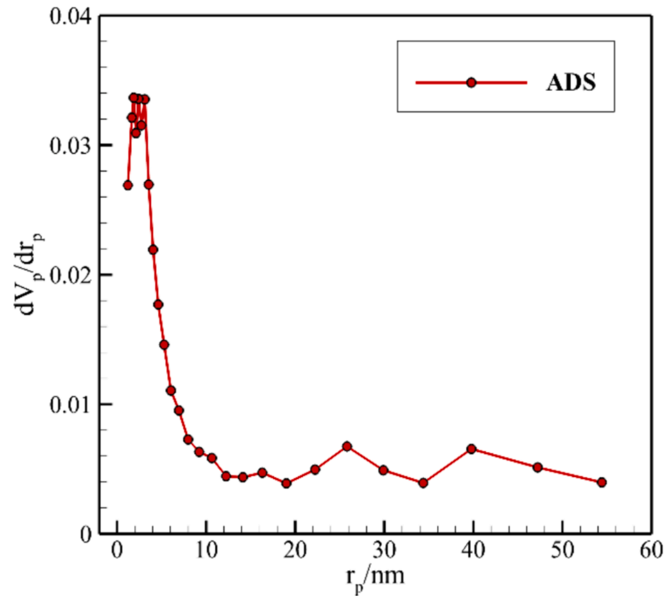

Fig. 6. BJH curves for the sample.

2. Experimental procedure

2.1. Materials and methods

$CoFe_2O_4$ colloidal smart nanoparticles cluster synthesized based on solvothermal method reported in reference [38]. Based on amount of raw materials that precisely reported in reference [38] (also reported in Table 1), $FeCl_3.6H_2$ was dissolved in ethylene glycol. Then, $CoCl_2{\cdot}6H_2O$ and sodium acetate were dissolved in the fluid. The final solution was poured into autoclave. The autoclave was heated at 200 °C for 12 hr. Following the procedure, the particles were centrifuged, thoroughly washed, and dried.

2.2. Characterization techniques

To evaluate functional groups and organic compounds Fourier Transform Infrared (FTIR) spectroscopy was applied. In addition, in order to determine the size and morphology of these smart nanoparticles a Scanning Electron Microscope (SEM) was performed. The outcome of the SEM test is depicted in Fig. 2. As shown $CoFe_2O_4$ NPs with mean size particle about 11 nm are formed as spherical clusters.

Fig. 3 illustrates the FTIR spectra of the proposed magnetic compounds. The oxygen-metal interactions found in the octahedral and tetrahedral spaces are related to the climax at 554 cm^{-1} and 435 cm^{-1}, respectively [38]. Higher vibration frequency of oxygen-metal conjunctions in octahedral areas is caused by shorter conjunctions in tetrahedral area compared to octahedral area. It demonstrates that the vibration of oxygen-metal interactions within octahedral areas and tetrahedral areas, respectively, corresponds to the climax at 435 cm^{-1} and 554 cm^{-1}, respectively. In addition, C-O stretching conjunctions, $CH_2 = CH$ conjunctions, and CH_2 conjunctions, are ascribed to climax at 1590 cm^{-1}, 1089 cm^{-1}, 1418 cm^{-1}, 883 cm^{-1}[39]. The C-O and C-H conjunctions connected to the molecules of ethylene glycol on the nanoparticles' surface. Regarding the OH group, the intense rise at 3721 cm^{-1} is present [40].

The XRD outcome of $CoFe_2O_4$ NPs is depicted in Fig. 4. Regarding the small particles' size local line is wide. All peaks observed in the diffraction pattern are in good agreement with the crystal structure of spinel ferrite. Using the Debye-Scherrer relation and applying corrections demonstrated that the grain size is 11 nm. Considering that the critical diameter of single domain for magnetite nanoparticles is 12.4

Fig. 7. The cobalt ferrite ethylene glycol–water magnetocaloric nanofluids samples.

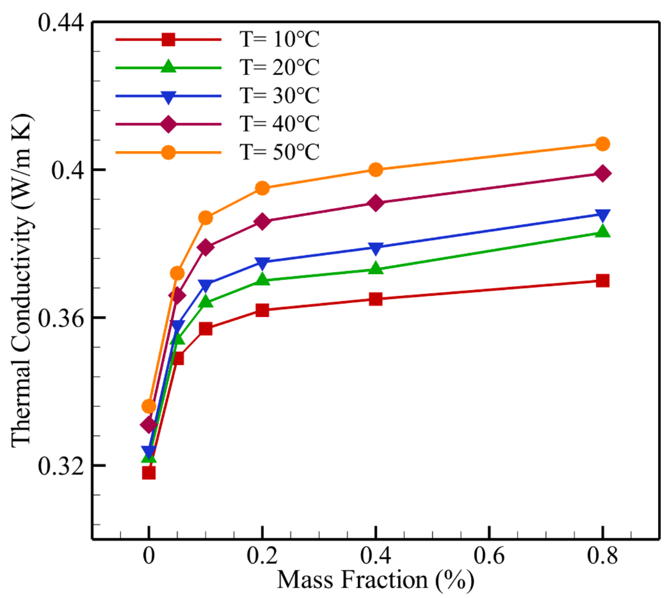

Fig. 8. Variation of thermal conductivity versus mass fraction at different temperature.

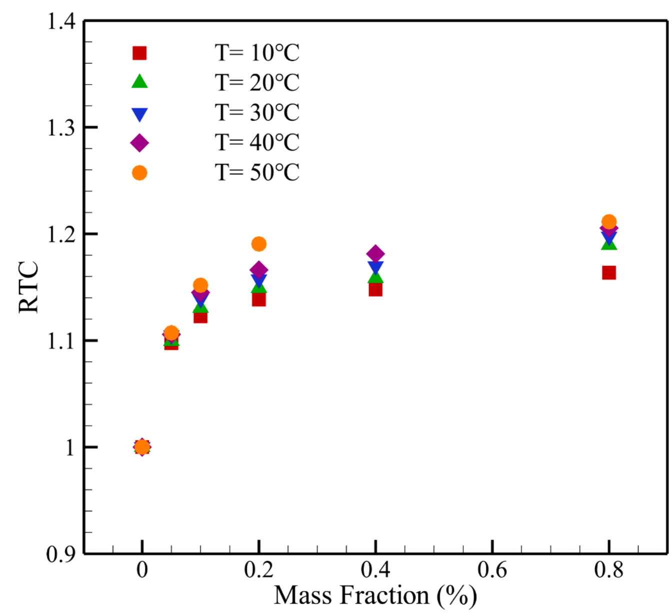

Fig. 9. The relative thermal conductivity versus mass fraction at different temperature.

nm, the synthesized nanoparticles are singular domains, it can be said [41].

To evaluate the specific surface area, the BET (Brunauer, Emmett and Teller) method is utilized (Fig. 5). Specific surface area 127 m^2g^{-1} was obtained. Also, pore volume size dissemination was evaluated according to BJH (Barrett Joyner Halenda) method. BJH curve presented in Fig. 6 depicts radius dissemination of pores within the nanoparticles.

2.3. Preparation of cobalt ferrite ethylene glycol–water magnetocaloric nanofluids

In this research, the synthesized cobalt ferrite colloidal nanoparticle dispersed by a 2-step method in EG-water (50:50) coolant base fluid at different mass concentrations, i.e., 0.05 %,0.1 %, 0.2 %, 0.4 %, and 0.8 % as shown in Fig. 7. First, the specified quantity of surfactant Carboxymethyl cellulose (CMC) was added to the BF, then it was combined with a magnetic stirrer for a specified time of 20 min. Then, the NPs were added to the BF in a specific mass percentage and mixed with a magnetic stirrer for 45 min. This process continues until a stable colloidal mixture is created. To prevent clumping and accumulation of these smart nanoparticles as well as stable suspension, ultrasonic waves have been used for 20 min for each sample. Also, due to the use of surfactant and the stability of the magnetocaloric nanofluids, as well as to prevent the loss of the properties of the surfactant, the experiment has been carried out in the temperature range of 10 to 50 degrees Celsius. Devices utilized to make magnetocaloric nanofluids are mentioned in Table S1. The amount of required BF (EG + Water) and NPs for this magnetocaloric nanofluid at various mass fractions are calculated by using Eq. (1) [42].

$$\varphi = \left(\frac{m_{NP}}{m_{NP} + m_{Water} + m_{EG}}\right) \times 100 \tag{1}$$

2.4. Experimental measurements

KD2 pro was utilized in this experiment to ascertain the thermal conductivity of cobalt ferrite colloidal/EG-water-NFs. It was calibrated with glycerol, a reference fluid, prior to the test. The KS-1 sensor needle with a length of 60 mm and a diameter of 1.3 mm is used in this

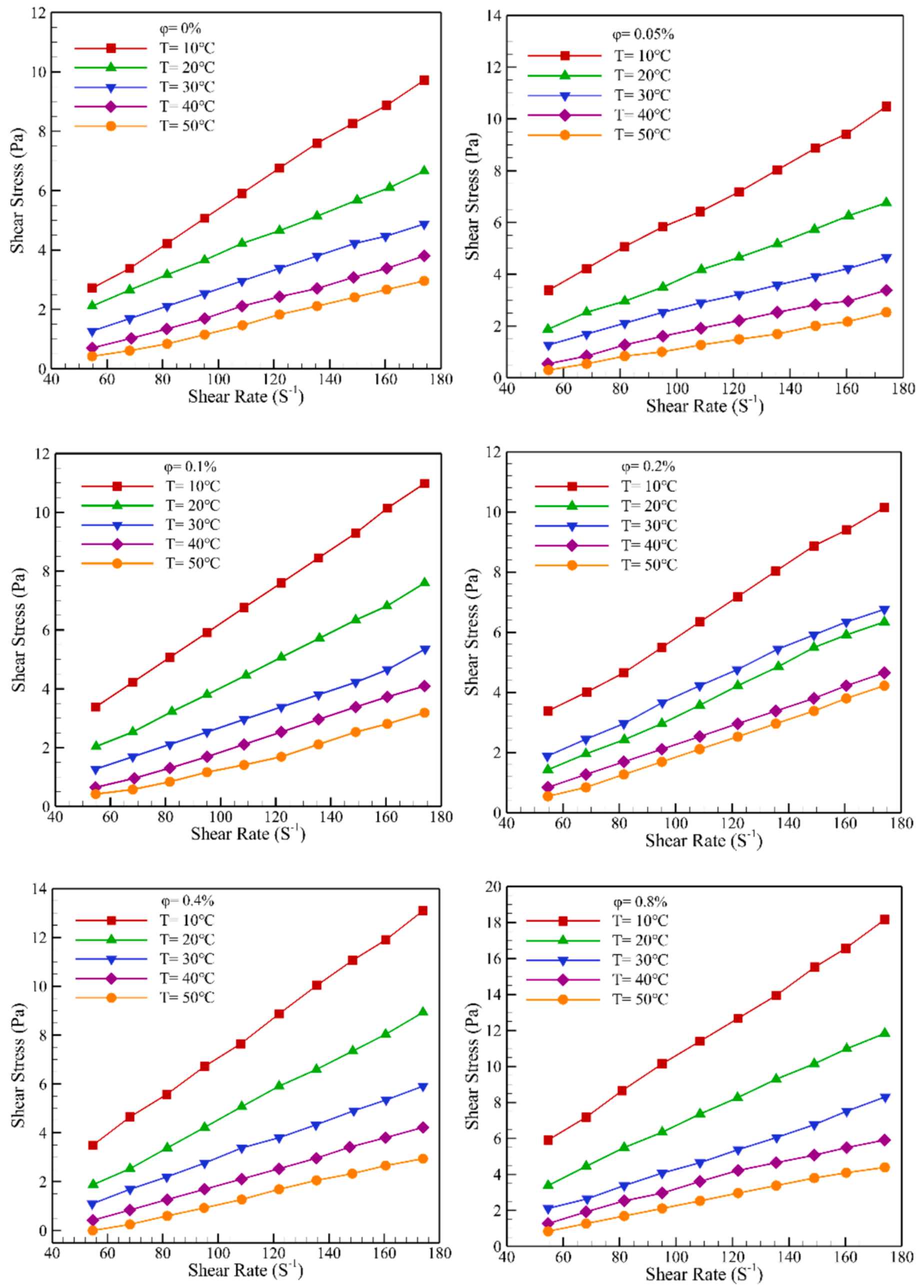

Fig. 10. Variation of shear stress versus shear rate at different temperatures and mass fractions.

instrument to detect thermal conductivity with a precision of 3 % between the 0.2 and 2 W/m.K. A calibrated Brookfield viscometer which is depicted in Fig. S1 was utilized to measure the viscosity of proposed magnetocaloric nanofluids.

3. Results and discussion

The present research, has determined the thermal conductivity of cobalt ferrite colloidal/EG-water-NFs in the range of 10 to 50 °C. Fig. 8 demonstrates the variation of thermal conductivity at various temperatures in terms of mass concentration. Results reveal that increasing mass fraction leads to an enhancement in thermal conductivity. The reason can be attributed to the nanoparticles clustering [43]. Many factors affect the thermal conductivity of NFs. According to the literature [43], nanoparticles Brownian motions, nanofluids clustering, thermophoretic impact, ballistic transport, nonlocal impact, and liquid Nanolayering at the interface are some of the effective parameters of thermal conductivity increment. In addition, temperature affects thermal conductivity. Also, thermal conductivity can be related to viscosity, Brownian motion, and particle aggregation. Fig. 8 shows that an increase in temperature leads to an increase in thermal conductivity. Increasing the temperature, increases kinetic energy of the particles, increases Brownian motion, and thus reduces segregation [43]. In addition, the initial increase in thermal conductivity at low particle concentrations is due to efficient heat transfer through the added conductive particles. However, as the particle concentration exceeds a certain threshold, the increase in thermal conductivity becomes less significant. This change is explained by the percolation effect, where the particles form a continuous path for heat transfer. Once this path is formed, additional particles have a smaller impact on thermal conductivity. The percolation threshold is the point at which the particles form a large cluster, allowing for easier heat transfer. Beyond this threshold, further increases in particle concentration have a diminishing effect on thermal conductivity improvements. To have a better understanding

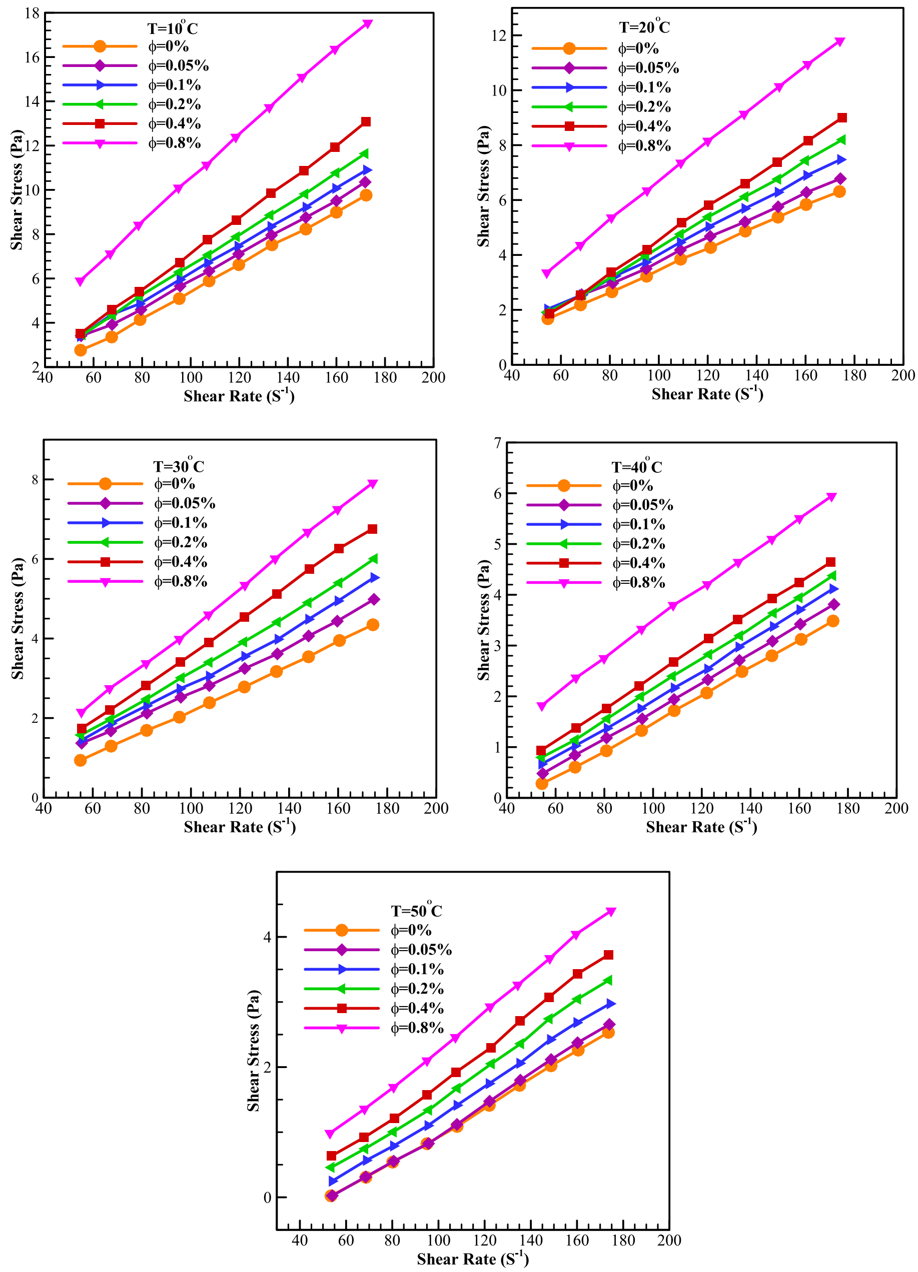

Fig. 11. Variation of shear stress versus shear rate at different mass fractions and temperatures.

about the variation of thermal conductivity, Relative Thermal Conductivity (RTC) is defined as the Eq. (2) [44].

$$RTC = \frac{k_{NF}}{k_{BF}} \tag{2}$$

The higher the temperature at a constant mass fraction, caused the higher the RTC percentage. According to Fig. 9, the maximum and minimum relative thermal conductivity of magnetocaloric nanofluid relates to the 0.8 % and 0.05 % of the nanoparticles fraction at T = 50 °C and T = 10 °C, respectively. At T = 10 °C, nanoparticles concentration enhancement up to 0.8 % leads to an increment of thermal conductivity of 6 %. Also, at T = 50 °C by increasing nanoparticles concentration up to 0.8 %, thermal conductivity enhanced by 9.4 %. By comparing the results obtained through the KD2 test with the results of Kharat et al. [45], we conclude that adding water to the ethylene glycol base fluid increases the thermal conductivity value of the nanofluid under the same conditions.

Fig. 10 illustrates the variation of shear rate as a function of shear stress at range of 10–50 °C, and various nanoparticles mass concentrations, i.e., 0, 0.05 %, 0.1 %, 0.2 %, 0.4 %, 0.8 %. The fluid type and whether it is Newtonian or non-Newtonian are shown by the shear stress-shear rate graph's pattern. When shear stress changes linearly with shear rate, a fluid is Newtonian; when shear stress changes non-linearly with shear rate, a fluid is non-Newtonian [46]. Based on Fig. 10, cobalt ferrite ethylene glycol–water magnetocaloric nanofluid is a non-Newotonian fluid. This is explicit evidence that magnetocaloric nanofluids at different concentrations have a non-Newtonian characteristic similar to the BF. Moreover, the supplement of NPs to the BF does not have a substantial influence on the non-Newtonian characteristic of that. The impact of temperature on dynamic viscosity is what caused the enhancement on the line in the graph. The result is consistent with the literature [47]. It is obtained that by enhancing temperature, the line slope is decreased. The line slope in temperature 10 °C is substantially higher than 50 °C. Upon examining Fig. 11, it becomes evident that the

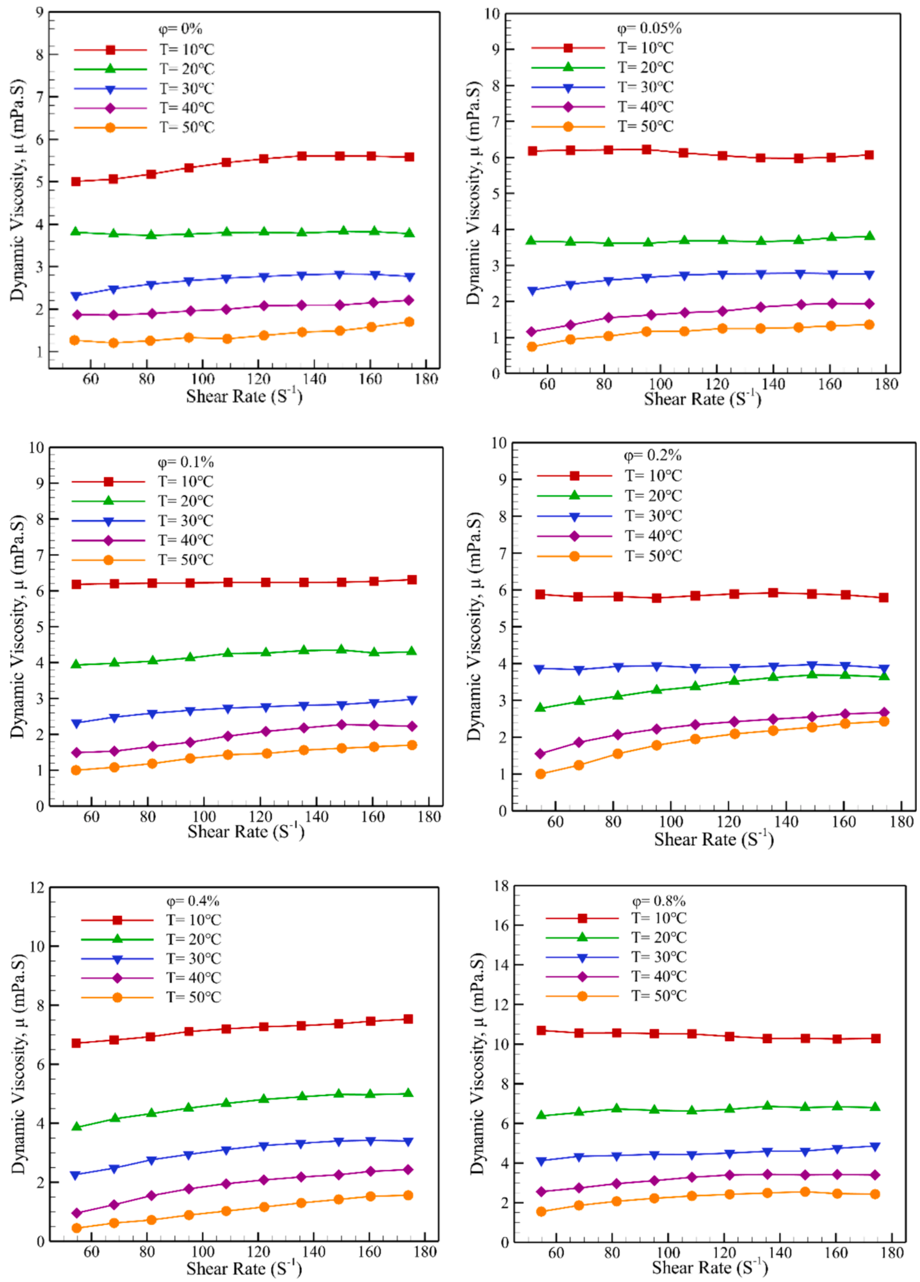

Fig. 12. Variation of dynamic viscosity versus shear rate at different temperature and mass fraction.

shear stress magnitude rises as the nanofluid concentration increases while maintaining a constant temperature. However, this value diminishes as the temperature increases. This phenomenon can be attributed to the fact that as the liquid temperature rises, its resistance to external forces decreases, resulting in a decrease in shear stress.

Viscosity variation in terms of shear rate demonstrates the non-Newotonian trend in Fig. 12. Also, it is revealed that the viscosity is decreased by temperature enhancement. The resistance of the fluid in front of the applied forces is viscosity which leads to shear rate creation. In addition, based on a comparative analysis of the findings from this study and previous research [48], it can be inferred that the utilization of $CoFe_2O_4$ particles is more favorable than Fe_3O_4 particles for the preparation of a magnetocaloric nanofluid. This preference stems from the ability to achieve a nanofluid with reduced viscosity by selecting an optimal percentage of base fluid composition (ethylene glycol and water) and employing an appropriate concentration of nanoparticles. The utilization of a nanofluid with lower viscosity not only enhances pumping power efficiency but also contributes to energy conservation in self-power devices. Also, the use of machine learning and optimization methods that have been used in some other scientific fields [49–51] and their combination with the results of using magnetocaloric nanofluids in self-power devices is recommended and can be considered for future studies.

Fig. 13 depicts the variation of dynamic viscosity in terms of temperature, i.e., 10–50 °C, at various nanoparticles mass fractions and a specific shear rate of 108.5 (S^{-1}). Generally, the dynamic viscosity of nanofuild is substantially higher than the BF at the temperature range of 10–50 °C. The enhancement in fluids' temperature has resulted in the dynamic viscosity reduction. The highest amount of viscosity was obtained at 10 °C for magnetocaloric nanofluid with 0.8 % concentration. By enhancing the magnetocaloric nanofluids' temperature, the dynamic viscosity for both the NF and the BF has a recurring trend. The reason is that at the higher temperature, the molecules and particles' mobility is higher which leads to an improve in their kinetic energy. Enhancement

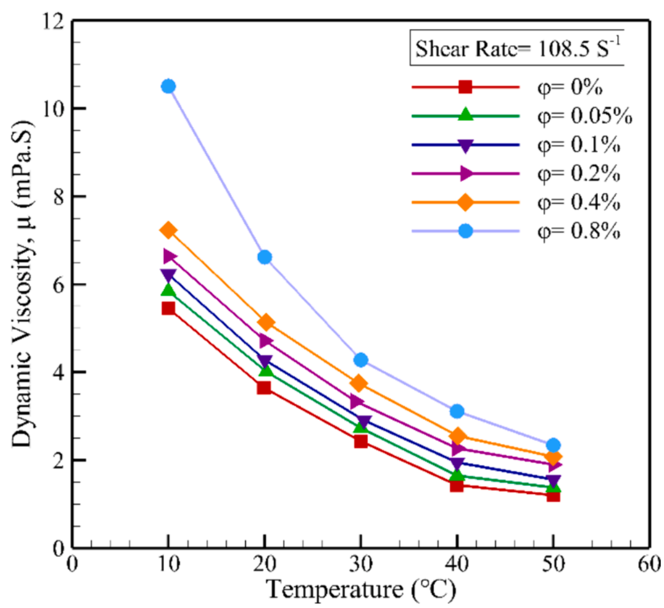

Fig. 13. Variation of dynamic viscosity versus temperature.

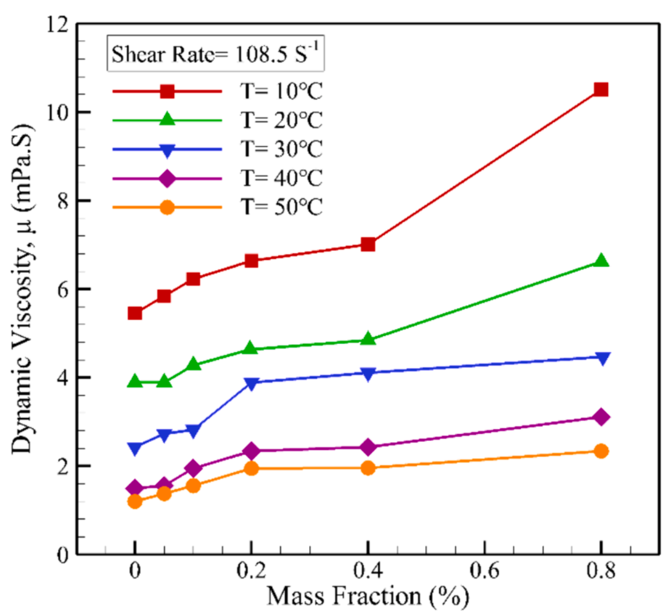

Fig. 14. Variation of dynamic viscosity versus mass fraction.

of the temperature also decreases the intermolecular forces and leads to molecular bonds broken.

As can be seen in Fig. 14, nanoparticle concentration enhancement has resulted in an ununiform increament in dynamic viscosity. This increment is more in a lower temperature in comparison to a higher temperature.

4. Conclusions

The present research has evaluated the dynamic viscosity and thermal conductivity of the $CoFe_2O_4$ colloidal NPs in water-EG coolant BF at the range of 10 °C to 50 °C and five NPs mass concentrations, i.e., 0.05 %, 0.1 %, 0.2 %, 0.4 %, 0.8 %. Moreover, the behavior of NFs is analyzed based on the plots' non-linear trend of shear stress and viscosity in terms of shear rate. The following facts are extracted from this study.

1) Applying $CoFe_2O_4$ colloidal NPs to the water-ethylene glycol coolant base fluid improves thermal conductivity. Nanoparticles fraction enhancement increases thermal conductivity. Also, temperature enhancement leads to an increment in thermal conductivity.
2) By increasing the concentration of nanoparticles in the suggested magnetocaloric nanofluids, the dynamic viscosity is increased. This increment is more intensive at 0.8 % mass fraction. In addition, temperature growth leads to the significant reduction of dynamic viscosity by up to 77.7 %.
3) According to the non-linear trend of shear stress as a function of shear rate figure and viscosity versus shear rate plot, the $CoFe_2O_4$ / ethylene glycol–water magnetocaloric nanofluids have a non-Newtonian status.
4) By measuring the rheological behavior of this nanofluid, it can be seen that this nanofluid is very suitable for use in all self-powered devices with magnetic ability.

Since this study was conducted experimentally, the results of this study can be used for numerical simulations. It is also recommended to use artificial neural networks and response surface methods for the future research.

CRediT authorship contribution statement

Ahmad Reza Abbasian: Conceptualization, Software. **Mohammad Hossein Razavi Dehkordi:** Investigation, Methodology. **Noushin Azimy:** Formal analysis, Resources. **Hamidreza Azimy:** Conceptualization, Writing – original draft. **Mohammad Akbari:** Supervision, Writing – original draft, Writing – review & editing. **Badreddine Ayadi:** Data curation, Software. **Walid Aich:** Data curation, Funding acquisition. **Lioua Kolsi:** Data curation, Funding acquisition, Validation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.mseb.2024.117462.

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