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RESEARCH PAPER

Efficacy of Natural Coagulants in Treating Sugar Industry Effluents

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ABSTRACT
Industrial sector is understood to be one of the major offenders in polluting environment particularly water among others. Sugar industry is one among the agro-based industry releasing high organic pollutants rich in BOD. Though conventional treatment methods have been employed in treating sugar industry effluents at varied degrees, they come with their own setbacks. In this direction natural coagulants are explored and evaluated for their potential and efficiency towards treating sugar industry effluents. The process of coagulation and flocculation removes impurities precisely colloidal impurities through the phenomenon of destabilization, bridging and sweep coagulation. In order to have an effective treatment factors governing coagulation are to be optimized to determine the dose, pH, mixing time etc. The prime objective of the present study is to characterize the sugar industry effluents, test the efficiency of both chemical and natural coagulants to treat these effluents and bring out a comparison and potential of natural coagulants with that of chemical coagulants. Jar test apparatus was employed all coagulation studies and the results were promising with reduction in parameters like colour (99.28%), electrical conductivity (60.39%), turbidity (97.67%), chloride (69.23%) and total dissolved solids (60.42%) highest by ferric chloride followed by the natural coagulants. The findings of the study suggest that the lowest dose of 0.25g/l was optimum to remove the physico-chemical parameters both by chemical and natural coagulants and since natural coagulants were equally competent with chemical coagulants these can be substituted towards achieving green treatment options.
Keywords: Alum, Sago, Ferric Salts, Chitin Turbidity.

INTRODUCTION

Pollution of environment is exponentially increasing over the past few years reaching an alarming rate with reference to the impacts on life. Intensified industrialization along with urbanization is contributing to the overwhelming volumes of wastewater that is reaching the surface water bodies polluting the available fresh water resources with toxic and hazardous pollutants. Fresh water resource has become scarce and fragile being vulnerable to various pollutants. By 2025 nearly 60% of the population across world might face physical shortage of water. In order to meet the water demand by the ever-increasing population reuse of

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wastewater is understood to be one of suitable options for both periurban and urban irrigation in several countries.

Sugar industries play vital role in the economic development of the nation. Nevertheless, effluents generated from these industries possess high strength in terms of organic constituents. Nearly, 1,000litres of effluents per one tonne of sugar cane crushed is generated from these industries, if these are discharged without or improper treatment, they pose effects both on terrestrial and aquatic ecosystems (Kushwaha, 2015). Several conventional wastewater treatment methods are being used towards ensuring good quality of treated effluents but then each of them comes with their own setbacks.

With the advent of the concept of sustainability, research and development has been focussing on sustainable technologies, precisely green technologies with reference to wastewater treatment. One such technology is coagulation and flocculation using natural coagulants. Treatment using coagulation has been dates back to the earliest times with an objective to remove colloidal impurities so as to remove turbidity of the wastewater (Ronke et al., 2016). Coagulation is a physico-chemical treatment method based on the phenomenon of destabilization, bridging and sweep coagulation. Natural coagulants can be obtained from a number of sources which include plants, animals and microorganisms.

Industrial effluent treatment using natural coagulants has been focus of researchers during the last decade owing to the advantages of producing biodegradable sludge, low cost, availability etc (Yang et al., 2016). Further, blend of coagulants with combinations of chemical-natural, natural-natural towards enhancing the efficiency of treatment have also been the focus of these studies. Chitosan has been one of the mostly studied coagulant, described as non-toxic cationic linear molecule having high molecular weight (Thakur and Takur, 2014). The prime objective of the present study is to characterize the sugar industry effluents, test the efficiency of both chemical and natural coagulants to treat these effluents and bring out a comparison and potential of natural coagulants with that of chemical coagulants.

MATERIAL & METHODS

Coagulants alum, chitin and ferric chloride were of analytical grade supplied by Coastal Enterprises. All chemicals were purchased from Merck Chemicals unless otherwise specified. Sago was procured from local market, cleansed and powdered using a domestic blender. The powder was sieved through 0.25µ sieve to get uniform size. The powder was stored in a sealed polythene for further use.

The sugar industry wastewater was collected from the sugar industry located around 80km from GITAM Institute of Science, GITAM (Deemed to be University) using three 25 L sterile plastic-cans. After filling to the brim of the can it was then corked sealed and refrigerated until the commencement of the experiment.

Experiments to determine efficiency of coagulants was performed using conventional Jar test Apparatus (Cintex Flocculator). The experiments were carried out in batches and were conducted in triplicates and are represented as average. Each beaker was filled with one litre sample to which coagulant dose was added. Mixing speed was set to of 100rpm for 2min and 20rpm for 20min. After which the treated water was allowed to settle for a duration of 30min.

The characteristics of the effluent were determined according to the standard methods for the examination of water and wastewater (APHA, AWWA, WEF 2012). All experiments were conducted at the laboratory of the Department of Environmental Science. All gravimetric determinations were done on digital balance (Essae-Teraoka Ltd, Model: FB200)

having sensitivity up to 3 decimal places. Measurement of turbidity was done in terms of Nephelometric Turbidity Units (NTU) using turbidimeter (HACH 2100 Portable Turbidimeter, HACH, USA) (Table 1).

Table 1. List of physico-chemical parameters analysed pre and post coagulation experiments

Parameter	Method of Analysis
Colour	APHA Standard Method 2120
Turbidity	Hach Method 8237
pH	APHA Standard Method 4500
Electrical Conductivity	APHA Standard Method 2510
Hardness	APHA Standard method 2340
Calcium	APHA Standard Method 3500Ca-D
Chlorides	APHA Standard Method 4500 Cl^-
Total Dissolved Solids	APHA Standard Method 2540C

RESULTS AND DISCUSSION

Efficiency of chemical and natural coagulants to treat sugar industry wastewater was investigated in the present study. The results are presented as follows.

Table 2 presents initial analysis (raw water) of sugar industry wastewater. Values are presented as mean of 12 samples. pH was found to be 5.9. Turbidity were found to be 45NTU. Electrical conductivity of the initial analysis was found to be 1825µ siemens/ cm^2. Total dissolved solids concentration was 922mg/L. Chloride content of the samples was found to be 474mg/L. Concentration of total hardness was 1300mg/L and that of Calcium hardness was 800mg/L.

Table 2. Initial Parameters of Sugarcane industry effluents

Parameters	Initial Values
pH	5.9
Electrical Conductivity Micro siemens per centimetre)	1825
Turbidity in NTU	45
Chlorides in mg/l	474
Hardness in mg/l	1300
Total Dissolved Solids in mg/l	922
Colour in Pt-Co Scale	12
Ca Hardness in mg/l	800

Colour reduction of sugarcane industry wastewaters by four coagulants was observed to be highest with ferric chloride coagulant at pH 7 (99.28%) at dose 0.25g/l (Fig. 1). pH reduction of sugarcane industry wastewaters by four coagulants was observed to be highest with ferric chloride at pH 8 (30.13%) at dose 0.75g/l (Fig. 2).

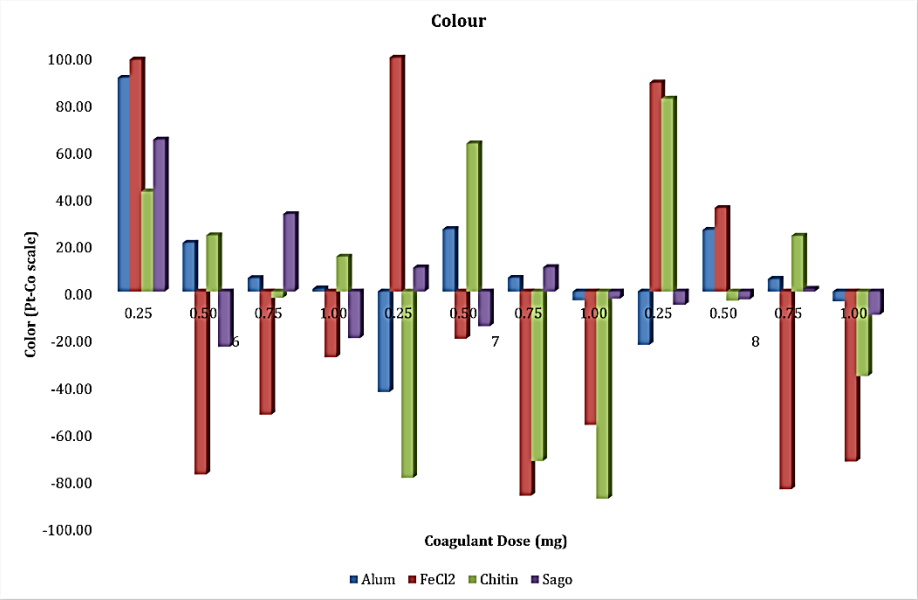

Fig. 1. Colour removal comparison of four coagulants

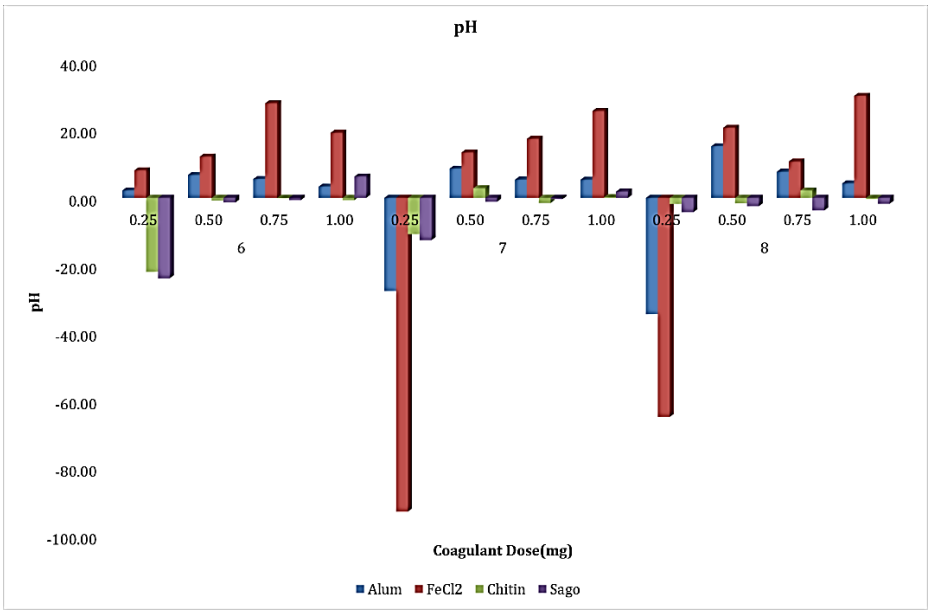

Fig. 2. pH reduction comparison of four coagulants

Electrical Conductivity reduction of sugarcane industry wastewaters by four coagulant was observed to be highest with ferric chloride coagulant at pH 8 (60.39%) with dose 0.25g/l (Fig. 3). Turbidity reduction of sugarcane industry wastewaters by four coagulant was observed to be highest with ferric chloride at pH 8 (97.67%) with dose 0.5g/l (Fig. 4).

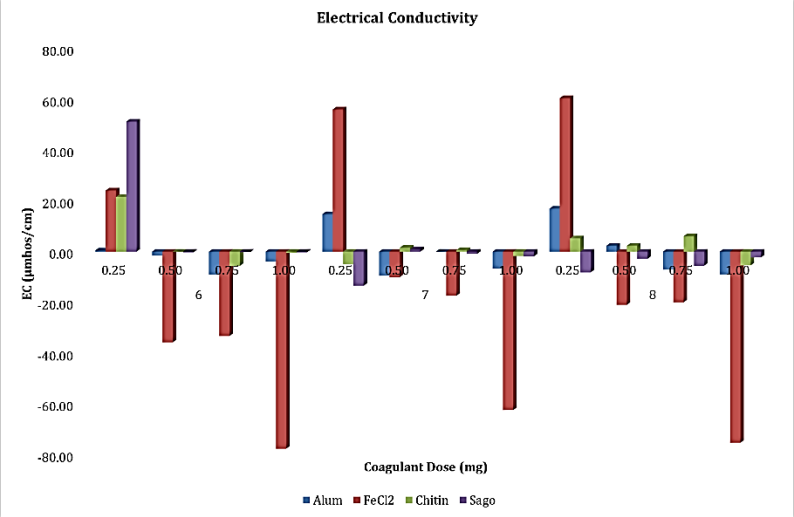

Fig. 3. Electrical Conductivity reduction comparison of four coagulants

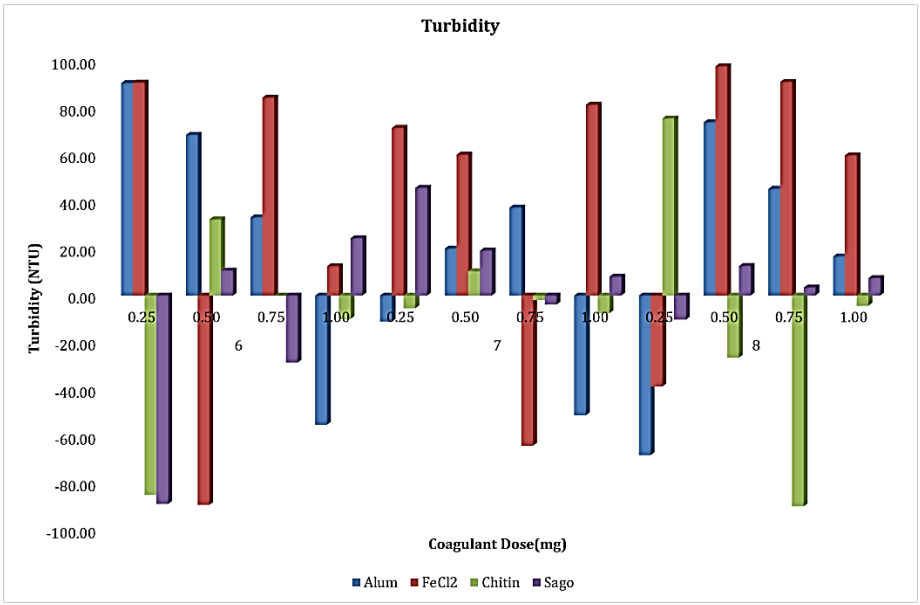

Fig. 4. Turbidity reduction comparison of four coagulants

Chloride reduction of sugarcane industry wastewaters by four coagulant was observed to be highest with ferric chloride coagulant at pH 7 (69.23%) with dose 0.25g/l (Fig. 5). Total Dissolved Solids reduction of sugarcane industry wastewaters by four coagulants was observed to be highest with ferric chloride at pH 8 (60.42%) with dose 0.25g/l (Fig. 6).

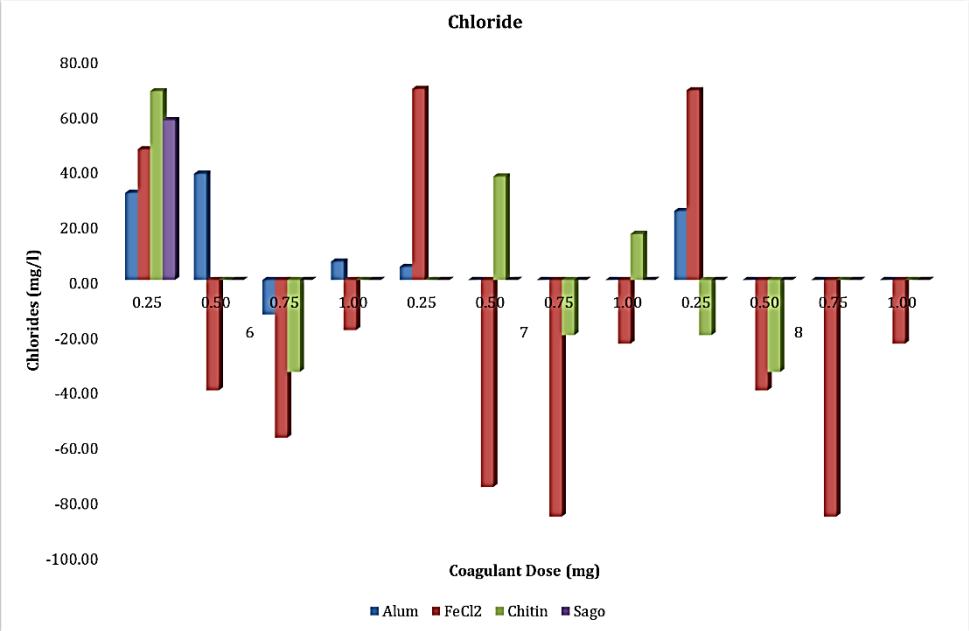

Fig. 5. Chloride reduction comparison of four coagulants

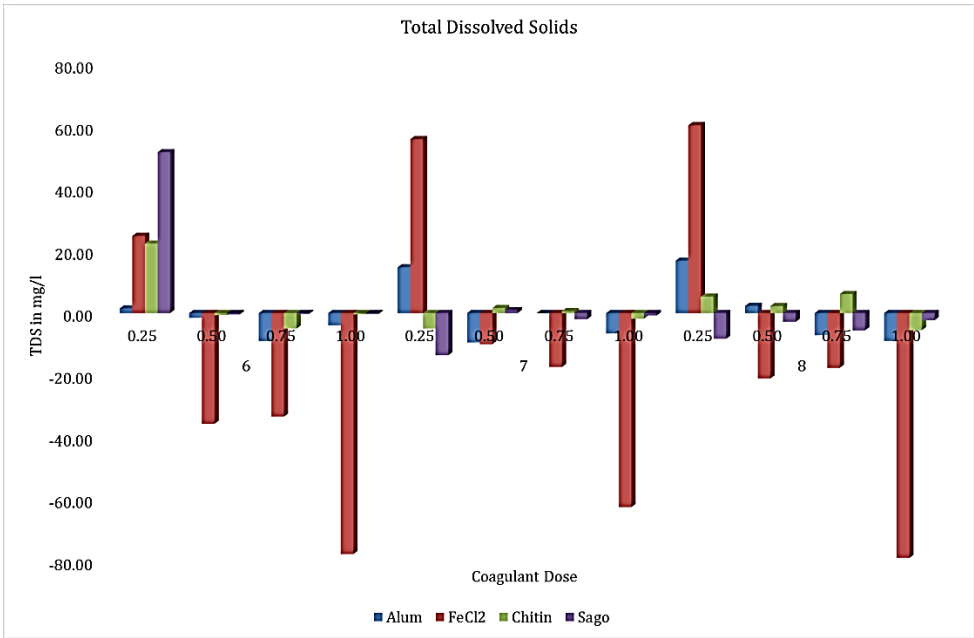

Fig. 6. Total Dissolved Solids reduction comparison of four coagulants

Efficiency of inorganic and natural coagulants was the objective of the present study. To start the study, we have initiated with analysing the physico-chemical characteristics of the sugarcane wastewaters. Further, the coagulation studies were carried out and the efficiency of chemical and natural coagulants are discussed.

In the present study the colour of the wastewater was measured spectrophotometrically on platinum cobalt scale and was found to be 12 units. Previous studies have reported that sugar industry effluents posses' colours like brown, reddish yellow, (Hampannavar and Shivayogimath 2010), black, and yellow. pH of the effluent in the present study was found to be 5.6. pH is understood to be an important parameter serving as an index of pollution. pH of the sugar mill effluent discharges from Tummapala sugar factory, Anakapalli (Andhra

Pradesh) was between 6.5 and 8.8. The total solids concentrations of wastewaters in the present study was found to be 922mg/l. TDS from Jayanthinala Sugar Industry wastewater was in the range of 488 mg/dm^3 (Hosetti et al., 1994), 400 to 1,650 mg/dm^3 of TDS was reported by (Maruthi and Rao, 2001). Chloride content of the wastewater in the present study was found to be 474mg/l.

Ferric chloride has shown greater and better removal of physico-chemical parameters over alum and hence the efficiency of ferric chloride is discussed in detail. The best performance by ferric chloride was reported at a dose of 0.25g/L. Dose of coagulant either in excess exerts phenomenon called electrical stabilization or repolymerization (Liang et al., 2009). Further, higher residual iron concentration induces color to the treated water. The better performance of ferric chloride at pH 6 can be attributed to the requirement of lower pH values by ferric ions in order to utilize organic functional groups as ligands, owing to the dominance of positively charged ferric hydrolysed species (Ryan et al., 2009). The performance of ferric salts is understood to be strongly related to organic fractions that are available in the wastewater (Rodrigues et al., 2014).

Natural coagulants for treatment of wastewater is understood to be a green and eco-friendly method as these are easily degraded and will not enhance the pollution load of the treated water. These are being extensively studied for their efficacy and their application for treatment of water as well as wastewater (Nimesha et al., 2021). When Tanfloc POP was used as a coagulant, greater removal of turbidity and color was obtained along with higher sludge volume indicating better removal of total solids from laundry wastewater (Nascimento et al., 2021). Joaquin et al., 2021 have achieved nearly 92% removal of both total suspended solids and biological oxygen demand with a dose of 72.3mg/L of C.lanatus as coagulant. Further, tannin-based coagulants have proved to be effective in treating leachate from landfill along with recovery of nitrogen (Righetto et al., 2021).

The quality of sago starch is relatively high owing to the presence of amylose and amylopectin. It possesses greater content of amylose. These properties ascertain sago starch to be a natural binder (Teng et al. 2011; Aziz and Sobri, 2015). For removal of turbidity, it is essential to select the appropriate type of starch as a coagulant. Lower efficiency of sago starch in comparison to chemical coagulants can be attributed to the non-ionic characteristics which might hindered the process of interparticle bridging mechanism resulting in failure to destabilize colloidal particles in the effluent. Xing et al., 2005 suggested that the performance of starch can be enhanced by activating the starch by introducing small amounts of hydrophobic or ionic groups into the polymers.

Effective functional groups for coagulation and flocculation are carboxyl, hydroxyl and amino groups which are all present in sago starch (Abdel-Aziz et al., 2011). Further, hydroxyl and carboxyl groups are reported to enhance the flocculating efficiency through bridging mechanism (Awang and Aziz, 2012). It is also reported that coagulants having high molecular weights are efficient in enhancing bridge-formation capability of colloidal impurities resulting in development of good size floc for better settlement and removal (Gao et al., 2002).

The mechanism of coagulation by chitin characterized by polysaccharide-based materials is reported to be different in comparison to conventional adsorbents. These are complicated encompassing different interactions which are dependent on pH as it might affect the protonation of these macromolecules (Crini, 2005). Several researchers have taken up comparative studies among chitin and chitosan for treatment of wastewater (Terkula et al., 2021). The efficiency of removal of suspended solids, colour, chemical oxygen demand from sugar industry effluents was enhanced with increasing dose of chitosan to an optimum dose beyond which no improvement was observed (Pambi and Musonge, 2015). Under alkaline

conditions the performance of chitosan was observed to be decreased owing to the gelation. Moreover, overdosing resulted in destabilization of the neutralized flocs impeding their settlement.

It is observed from the study that natural coagulants are equally efficient and they can be processed and progressed from perspectives of sustainability but are opposed for their commercialization and acceptance owing to two major hinderances such as feasibility and practicality of real time applications. In this connection the present study can be extended to field scale to get more insights and sustainable acceptance of natural coagulants beyond environmental, social, technical and economic aspects (Ang and Mohammad, 2020; Karnena et al., 2021).

CONCLUSION

The efficiency of the chemical coagulants, alum, ferric chloride and ferrous sulphate were applied for the treatment of wastewater from sugar industry. Results from the present study illustrated good removal of physico-chemical characteristics like electrical conductivity, turbidity, color and total dissolved solids at the least dose of 0.25g/l. Following conclusions can be made from the results obtained in this study:

(1) As per the experimental conditions applied along with the characteristics of the wastewater, sago starch illustrated least effectiveness owing to the absence of ionic properties. However, it has been competent with other natural coagulant of the study chitin and ferric chloride. As per the discussion enhancing the efficiency of sago starch might be possible by activating the starch with ionic groups.

(2) Coagulant dose, one of the important parameters was found to be governing factor influencing the efficiency of all the coagulants under test and process performance. Least doses of 0.25g/l was found to be effective by all coagulants.

(3) Improved treatment performances were obtained at pH 6, in slightly acidic conditions, by natural coagulants as well while ferric chloride. However, further investigations using a broader pH range should be carried out to provide a better understanding on the influence of pH over the coagulation–flocculation.

The results of this study showed, that although conventional coagulation process using alum, ferric chloride are effective for removing of the contamination at different concentrations, natural coagulants were equally competent at lower doses and wide range of pH.

GRANT SUPPORT DETAILS

The present research did not receive any financial support.

CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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