OPINION

on a competition for the occupation of the academic position of **"Associate Professor"** in the field of higher education **4. Natural sciences, mathematics and informatics,** professional direction **4.5. Mathematics**, scientific specialty **"Mathematical modelling and application of mathematics (Mathematical Biology)"**, announced for the needs of the Institute of Mathematics and Informatics at the Bulgarian Academy of Sciences in SG No. 14/10.02.2023 with a **single candidate Head Assist. Prof. Dr. Milen Kolev Borisov from IMI-BAS**

The opinion was prepared by *Prof. Dr. Nevena Petrova Ilieva-Litova* (IICT-BAS and IMI-BAS), member of the scientific jury for the competition according to Order No. 184/07.04.2023 of the Director of IMI-BAS

1. Brief biographical data about the candidate

The only applicant under the current procedure, Dr. Milen Borisov, assistant professor, graduated from the Faculty of Mathematics and Informatics of the Sofia University "St. Kl. Ohridski", with a Master's degree in Informatics (Bio- and Medical Informatics) in 2008. Immediately after graduation, he began doctoral studies, joint between the Faculty of Mathematics and Informatics of the Sofia University "St. Kl. Ohridski" and the Institute of Mathematics and Informatics – BAS, with scientific supervisor Prof. Dr. Neli Dimitrova. In 2013 he successfully defended his doctoral thesis on "Investigation of food chains in a hemostat: stability and bifurcation of equilibrium points". In parallel, he worked as a programmer in a software company, and in 2010 he started working at the Institute of Mathematics and Informatics – BAS, initially as a programmer, then as an assistant, and later as a head assistant.

From the very sparingly presented data in the resume, it can be seen that the candidate has experience in working on scientific projects, as well as basic skills in their independent organization and implementation through the BAS program for supporting young scientists, which aims precisely at gaining such experience. Participation in more than 30 scientific seminars and conferences is indicated, but there is no information about their nature or the nature of his participation.

The candidate also has some teaching experience – conducting exercises for an elective course at the FMI of the Sofia University "St. Kl. Ohridski".

2. General description of the presented materials

To participate in the competition, the candidate has submitted all the documents required by the Law on the Development of the Academic Staff and the specific requirements for the relevant procedure according to the Regulations for the Acquisition of Scientific Degrees and the Occupancy of Academic Positions at IMI-BAN, including a scientific CV, a higher education diploma, diploma for the educational and scientific degree "doctor", a list of scientific publications, both those submitted

for participation in the competition, and a complete list of all publications, noticed independent citations (again, both of the publications submitted for participation in the current competition, and a general list), author's reference for the contributions in the publications presented for the competition, reference for meeting the minimum requirements for occupying the academic position "Associate Professor", reference for work experience in the specialty. In my opinion, the presented materials are in accordance with the legal requirements, as is the conclusion of the special commission at IMI-BAN, which certified the correctness of the applicant's documents.

For participation in the competition, Dr. Milen Borisov submitted 11 publications, distributed as follows (the points are according to the weighting coefficients accepted in the BAS for the scientific direction 4.5 Mathematics) – Table. 1.

In accordance with the requirements of the LDASRB and the Regulations for its application, three of the presented publications with a total of 100 points replace the habilitation work for the relevant procedure. The publications have not been used in previous procedures.

Table 1

Publication type	number	unit points	points
Q1	1	50	50
Q2	5	40	200
Q3	1	30	30
Q4	-	24	-
SJR	2	20	40
Other bases	1	12	12
Non-indexes	1	-	-
Score	11		332

3. General characteristics of the candidate's scientific and applied-scientific activity

The publications submitted for participation in the competition are focused on the field of professional expertise of the candidate – Mathematical Biology, with the appropriate clarification made by him himself – Biomathematics. Although divided by the candidate into three groups, they are all essentially related to the modeling of macroscopic dynamic processes in biological systems using systems of ordinary differential equations.

The first and most significant group in terms of volume and results is related to studies of processes in continuous bioreactors. This group includes 7 of the 11 publications submitted for the competition, four of which are in journals with an impact factor (one in quartile Q1, two in quartile Q2 and one in quartile Q3). The considered continuous bioreactors are of different types: for wastewater treatment, for the production of biogas and for the production of methane and hydrogen. These studies are of not only scientific, but also applied interest in the context of environmental problems and the need to abandon fossil fuels.

The second group, dedicated to the problems of reaction networks and their applications in biomathematics, contains three publications, two of them in impact-factor journals in quartile Q2. The focus here is on dynamical aspects of the correspondence between a reaction network and a growth model in the context of specific applications.

The third group – research in the field of mathematical epidemiology – contains only one publication (in quartile Q2), but the candidate has rightly noted the belonging to this field of some of the results of the second group.

The articles submitted for participation in the competition reflect the candidate's gradually expanding scientific interests and his skills for working in different teams. In addition, one of the publications has a co-author from abroad. Information about his personal contributions in the individual results is presented, which is important given the adopted alphabetical order when arranging the authors.

4. Main scientific and applied-scientific contributions of the candidate

Dr. Milen Borisov's most significant original contributions are in the field of *bioreactor research*. For the modeling of single-phase and two-phase anaerobic biodegradation processes, with the production of methane (biogas) or methane and hydrogen, respectively, the classical single biomass/single substrate model of methane fermentation has been upgraded in several aspects: two-component biomass modeling and introduction of a time delay, and for the two-component model, two different delay parameters have been introduced, which allows a more adequate description of the biochemical processes taking place in the reactor.

The following original results were obtained for the models thus modified:

- The asymptotic stabilizability of the model, implemented with the help of feedback directly related to the output of the process and the discrete time delay, was investigated, where a non-trivial equilibrium point was found and the convergence of the solutions to it was shown for sufficiently small values of the delay;

- The global stabilizability to a pre-selected non-trivial equilibrium point of the monocomponent model using partial-constant feedback was shown;

- An optimization iterative numerical algorithm with respect to the output (methane production) working in real time was developed and applied to all the investigated models.

The next group of models are those of *two-phase anaerobic biodegradation* (ABD), i.e. describing processes in two coupled bioreactors. They were obtained by adapting a single-phase model, and at a later stage a more complex structure of the products obtained in the two bioreactors was added. For the thus formulated and implemented new mathematical model consisting of 10 ODE for the first phase and 2 ODE for the second phase, respectively 13 ODE for the first phase and 7 ODE for the second phase, is:

- Proven the existence and uniqueness of uniformly bounded positive solutions, with locally stable equilibrium points with respect to practically important input parameters;
- Established the presence of a maximum of the input-output static characteristics in relation to the production of hydrogen and methane;
- Obtained an optimal ratio of the working volumes of the two bioreactors, assuming that they operate in the vicinity of the maxima of the input-output static characteristics in terms of hydrogen and methane yield as a function of the control variable. This theoretical result was essentially validated through the construction of a laboratory bioreactor for two-phase ABD of lignocellulosic waste (wheat straw) at the Stefan Angelov Institute of Microbiology at the BAS.

A mathematical model with significant applied potential in the management and optimization of bioreactors (hemostat) for the simultaneous biodegradation of mixed substrates in wastewater, on the example of the bio-degradation of a mixture of phenol and sodium salicylate, is also considered. Shown for this model are:

- The existence and uniqueness of non-negative solutions and global asymptotic stabilizability of the dynamics;

- The presence of two equilibrium points depending on the discharge rate of the bioreactor, considered as a key parameter of the model.

The second group of original contributions is related to studies of *reaction networks and their applications to biological tasks*. The problem here is in using the law of mass action outside its domain of validity – a solution in dynamic equilibrium. How well the essential characteristics of this environment adequately describe a given biological or biochemical process is a key question in potential applications. At the theoretical level, the following results were obtained:

- Reaction networks have been proposed for growth models close to the Gompertz model, with a modification in the description of the dynamics of the base variable through the introduction of an additional variable (of a "resource" type);

- A comparative analysis of three models was carried out: a dynamical system induced by a two-step exponential decay (2SED) reaction network involving three elements and two rate parameters, a classical SIR model and an intermediate variant of the SIR type model with a catalytic instead of a logistic contact mechanism, in which a correlation was established between the form of solutions and the type of contact mechanism;

- Within the framework of the model of the two-step process of exponential decay, numerical algorithms are proposed for the estimation of the rate parameters, taking into account the (in)accuracy of the epidemiological data.

The last two results could actually be referred to the third group of works (one article) in the field of mathematical epidemiology:

- A mathematical model of the immune response in dengue fever is proposed, which takes into account the simultaneous presence of mature and immature virions and is based on experimental data on the dependence of the response of dendritic cells on the type of virions produced by the infected cells. Numerical simulations allow distinguishing the immune response in primary and secondary infection.

5. Scientific indicators

The materials for the competition include a reference of compliance of the presented scientific publications and citations with the requirements of the LDASRB and the Regulations for its application and a candidate's reference of the original scientific contributions. These references cover the entire scientific activity of the candidate, which makes it possible to follow his scientific development, characterized by a focused topic and a visible gradation.

The research of Dr. Milen Borisov is met with interest by the scientific community, as evidenced by the data on independent citations of both the publications presented for the competition (32 citations) and his other scientific works (total of 50 as of 12/31/2022).

The publications and independent citations presented for this competition have not been used in other procedures and the points corresponding to them according to the above Regulations cover with a reserve – in some of the sections a large one – the minimum national requirements for professional direction 4.5. Mathematics. The specific requirements of IMI-BAS for occupying the academic position "Associate Professor" in this scientific field have also been met.

6. Critical remarks

I have no significant critical remarks and recommendations.

7. Personal impressions

I have known Dr. Milen Borisov since I started working in the "Mathematical Modeling and Numerical Methods" section of IMI-BAN in 2018. From the very beginning, I was impressed by his good preparation, his calm approach to solving problems and his and his way of unobtrusively offering his competence. His professional growth has been evident over the years and I believe the time is right for the next step and the new responsibilities and challenges that come with it.

8. Conclusion

The presented materials prove the necessary degree of professional maturity of Dr. Milen Borisov, the significance of his scientific achievements in the field of mathematical modeling and applications of mathematics, specifically in the field of mathematical biology, and the interest in them by the scientific community. There are also reasons to expect a further expansion of the circle of his scientific interests.

The requirements laid down in the Law on the Development of the Academic Staff for the candidates for the academic position of "Associate Professor", as well as the specific requirements for this position at IMI – BAS, are fulfilled by the candidate, in places with a significant reserve.

I am convinced that Dr. Milen Borisov is worthy to occupy the academic position of "Associate Professor" in professional direction 4.5. Mathematics, scientific specialty "Mathematical Modelling and Application of Mathematics (Mathematical Biology)" and I propose that the Scientific Jury recommend to the respected Scientific Council to make a positive decision on his candidacy for the competition announced for this specialty for the needs of the Section "Mathematical Modelling and Numerical Methods" to the Institute of Mathematics and Informatics at the Bulgarian Academy of Sciences.

25.05.2023   Signature:

/Prof. Dr. Nevena Ilieva/