DOI 10.22314/2073-7599-2018-12-3-22-27

Decomposition of Technological Processes for Evaluating the Performance of Production Line for PreSowing Treatment of Seeds

Ermat I. Kubeyev,
Dr.Sc. (Eng), Professor of Department,
kubeevei@ystu.ru;

Boris S. Antropov,
Dr.Sc. (Eng), Professor of Department

Yaroslavl State Technical University, Yaroslavl, Russian Federation

Abstact. An important step in improving the efficiency of crop production is the development of scientifically valid technologies and technical means of presowing preparation and treatment of seeds. Among the various methods that have a positive impact on crop growth, early maturity and resistance to adverse conditions, one of the most promising is seed pelleting. (*Research purpose*) The reasonability of the use of pelleted seeds (dragees) was shown the shell composition of which includes the substances necessary for active growth and increase resistance to adverse effects, and, in addition, it provides a more accurate seeding. We substantiate the need for improvements to existing technologies and agricultural equipment (for example, seed pelleting machine). due to the significant lack of hightech means of mechanization of seed presowing preparation at domestic agricultural enterprises. (*Materials and methods*) Experimental studies have been carried out with the use of computer mathematical modeling. Results of experiments were processed by methods of mathematical statistics, statistical analysis and data processing package, research application package, filtering, analysis and modeling of technological processes. Physical and mechanical properties and quality indicators of seeds and fillers have been determined in accordance with the applicable state standards. (*Results and discussion*) Use has been made of a program that includes obtaining information about the processes to solve the problems of experimental studies carried out by machines for pre-sowing treatment of seeds in accordance with the developed models of their functioning; the choice of the most effective means of measuring, recording and processing information about the operation of machines and equipment in normal operating conditions; as well as checking the effectiveness of the developed methods and tools to ensure the quality of the process in case of accidental disturbances. (*Conclusions*) The authors have studied main parameters and operating modes of a seed pelleting installation. An average values of the process parameters of the presowing treatment of seeds have been calculated under the conditions of normal functioning of machinery and equipment taking into account the validity and reliability of the obtained characteristics. The authors have developed the technological fundamentals of the artificial coating of seed surface. The study results can be used as practical recommendations for the organization of presowing treatment of seeds in order to increase seed germination and crop yields.

Keywords: information model, operations model, improving of presowing treatment, technological process, seed pelleting, production line.

For citation: Kubeyev E.I., Antropov B.S. Decomposition of technological processes for evaluating the performance of production line for the presowing treatment of seeds. *Sel'skokhosyaystvennye mashiny i tekhnologii.* 2018. 12(3): 18-22. DOI 10.22314/2073-7599-2018-12-3-22-27. (In Russian)

Pre-sowing treatment of seeds is preceded by a preparatory period, one of the tasks of which is to study the theoretical foundations of the operation of a pelleting installation, to work out a technique for processing experimental data and to interpret the results obtained. For this purpose, experiments have been carried out using the computer simulation method. In general, the technological process using various mathematical methods can be represented as a relation between the input $x_1(t)$, ... $x_n(t)$ and the output parameters $y_1(t)$, ... $y_k(t)$ [1-3].

Research of purpose is to improve the methods and means of experimental studies of the pre-sowing treatment including the study of the scheme, probabilistic characteristics and models of the functioning of pre-sowing seed treatment; mathematically represent the relationship between the input and output parameters of the technological process of pre-sowing seed treatment to determine unknown dynamic characteristics.

Materials and methods. The dynamic characteristic of the technological process of pre-sowing seed treatment can be represented as an unknown linear system [1]. It is advisable to consider it as an element that determines the relationship between the input and output parameters of the technological process (Fig. 1).

Research results. The information model of technological processes of pre-sowing seed treatment and the quality evaluation of their functioning can be represented in the form of the following structurally interconnected systems (Fig. 2) [4].

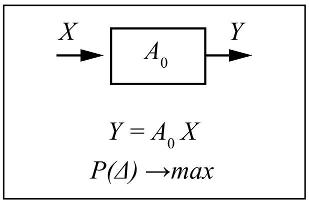

Fig. 1. General informational model with quality criterion

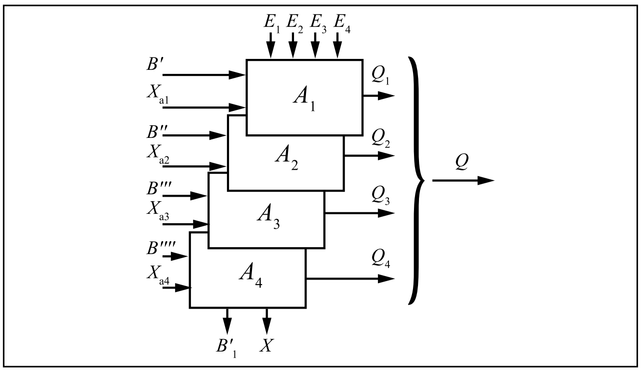

Fig. 2. Information model of technological processes evaluation of pre-sowing preparation and seed treatment

The optimization problem is reduced to maximizing the probability of maintaining the tolerance of the quantitative and qualitative parameters of each of the stages of the technological processes *Q*, where the selection of the vector of controlled parameters of the machine is represented as (X_{a1}, X_{a2}).

Because of the interference E_i, the tolerance preservation function may change, so we can speak about the maximization of its mathematical expectation.

$$Q_{cp} = [X_{a1}, X_{a2}, ..., E_1, E_2, ...B', B''...] = M[X_{a1}, X_{a2}, ..., E_1, E_2, ...B', B''...] = \int_{E\in\Omega}^{E\in\Omega} A_i [X_{a1}, X_{a2}, ..., E_1, E_2, ...B', B''...] P(E)\, dE, \quad (1)$$

where A_i is the transformation operator of the input vectors to the output ones; X_{a1}, X_{a2} ... – a set of machines for preparatory-and-final operations;

E_1, E_2 ... are the interference vectors determined by the properties of seeds and shell components; *B'*, *B''* – preparatory-and-final operations.

The procedure of multiparametric optimization is reduced to finding vectors *X* (one of the variants of preparatory-and-final operations) that satisfy the inequalities:

$$d_{js}[(X_{a1}, X_{a2}, ...)(E_1, E_2, ...)(B', B'', ...)] \geq Q, \quad (2)$$

$$Q^* < Q[(X_{a1} X_{a2},)(E_1, E_2, ...)(B', B'', ...)] < Q^0, \quad (3)$$

where Q^0, Q^* – a given level of the system quality and its minimum value, respectively.

Maximizing the probability of maintaining the tolerance does not involve achieving a maximum by all its components, which can take definite values and characterize the properties of the system.

It is generally accepted that the actual generalized system for estimating the probability of maintaining the tolerance Q^0 and a set of values of the additional estimated indicators q^+_e are less than or equal to the values of Q^0 and q^0 (parameters that satisfy the imposed constraints), and q^0_e may not reach extreme values.

Variants of technological processes for the preparation of seeds, protective-stimulating components and adhesive liquid can be expressed as:

$$\begin{Bmatrix} Q_1^0 \leq Q^0_{1доп} \\ Q_2^0 \leq Q^0_{2доп} \\ Q_3^0 \leq Q^0_{3доп} \\ \\ q_1^0 \leq q^0_{1доп} \\ q_2^0 \leq q^0_{2доп} \\ q_3^0 \leq q^0_{3доп} \end{Bmatrix}. \quad (4)$$

Compliance with these conditions requires that all operations should be performed observing agrotechnical requirements and ensuring necessary quality.

The tolerance for the current value of the output process (or operation) under the influence of random disturbances can be preserved if the input perturbations correspond to the tolerances. They were taken into account in making up a set of machines and equipment as dynamic systems. Thus, if the characteristics of the input perturbations and the operating modes of machines and equipment do not correspond to those permissible, the issue of maintaining the tolerance of the output technological process is incorrect as such. The maintenance of the output process tolerance *Y*(*t*) depends on the mode of operation of machines and equipment *U* and the tolerance $\Delta^{вх}_{x}$ on the current value of the input process *X*(*t*):

$$\Delta^{вых}_{y} = f(U, \Delta^{вх}_{x}). \quad (5)$$

In the case of a functional statistical connection between the input and output processes, the problem of estimating and maintaining the current tolerances of technological processes is solved in [4, 5].

The problem of estimating and maintaining the allowed values of output technological processes becomes especially difficult when the connection between the input and output processes is dynamic and is described by differential equations, and the tolerance fields are formed by random time functions (Fig. 3).

If input disturbances enter the input of dynamical systems, they are random time functions with their estimates of statistical characteristics: average values of *m*(*t*), variances D_x, probability density densities *f*(*x*),

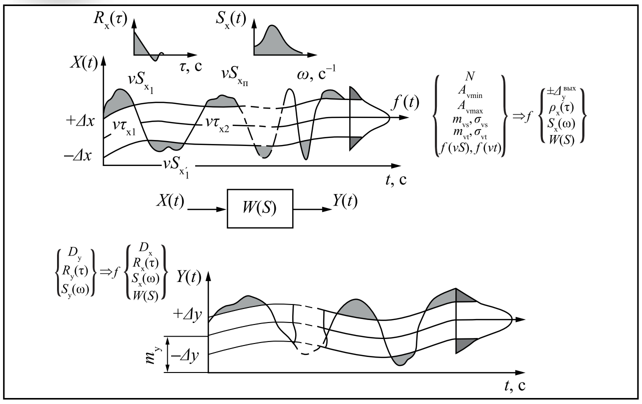

Fig. 3. Scheme of evaluation of permissible values of output processes in the dynamic functional relationship between the input and output processes of the machine

correlation functions $R(\tau)$ and their spectral densities $S(\omega)$, the following entry is valid:

$$\begin{Bmatrix} D_y \\ R_y(\tau) \\ S_y(\omega) \end{Bmatrix} \Rightarrow f \begin{Bmatrix} D_x \\ R_x(\tau) \\ W(S) \end{Bmatrix}, \quad (6)$$

where D_y, $R_y(\tau)$, $S_y(\omega)$ are the dispersion, the correlation function and the spectral density of the output process, respectively.

In accordance with expression (6) we obtain:

$$\begin{Bmatrix} N \\ A_{v\min} \\ m_{vs}, \sigma_{vs} \\ m_{vt}, \sigma_{vt} \\ f(vS), f(vt) \end{Bmatrix} \Rightarrow \begin{Bmatrix} \pm \Delta_y^{вых} \\ \rho_x(\tau) \\ S_x(\omega) \\ W(S) \end{Bmatrix}, \quad (7)$$

where $\pm\Delta_y^{вых}$ – tolerance for the current value of the output process; N – quantity of emissions for the established random level; A_{vmin} and A_{vmax} – the minimum and maximum ejection values, respectively; m_{vS}, σ_{vS}; m_{vt}, σ_{vt} – parameters of the mean value and the standard deviation of the square and duration of the outburst, respectively; $f(v_S)$, $f(v_t)$ are the values of the probability density of the distribution of the areas v_S and the duration of the emissions v_t, respectively.

When preparing seeds and other components for the process of artificial coating due to a change in their physical-and-mechanical properties, and also depending on the performance of the corresponding plants, the load mass $m_c(t)$, $m_n(t)$, $m_k(t)$ is transformed into the delivery mass $q_n(t)$, $q_k(t)$, respectively. At the preliminary stage of artificial coating, due to the interaction of the seeds $q_c(t)$ and the adhesive liquid $q_n(t)$, the physical-and-mechanical properties os the seeds change, which leads to a change in their rolling speed along the inner surface of the drum $v_c(t)$. At sufficiently high rolling speed (without detaching from the surface), the delivery of the filler $q_k(t)$ ensures the coagulation of the filler with the surface of seeds and their output with the artificial coating $q_d(t)$ [6-8].

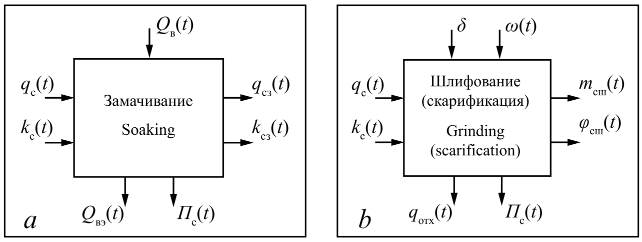

Fig. 4. Pre-sowing seed treatment model: a – soaking, b – grinding

For example, when treating seeds of essential oil plants before sowing, they are soaked instead of grinding, (Fig. 4) in order to remove (dissolve) the essential (etheral) shell containing inhibitory substances, in addition, the seeds undergo fermentation. To dissolve the essential (etheral) shell, it is necessary to change the water used for grain soaking. In this process, the loss of $\Pi_c(t)$ seeds is possible during the replacement of water [9-11].

When the artificial coating is applied in advance, grinding is typically performed (Fig. 4).

To ensure the required quality of the technological process, it is necessary to establish the required gap δ between the drum and plates and the speed $\omega(t)$. It should be noted that together with the waste $q_{max}(t)$, seed losses $\Pi_c(t)$ are possible.

Taking account of the above-mentioned facts, a model has been made for the functioning of technological processes of the preparation of seeds and other components and their treatment by the application of artificial coating (Fig. 5).

Calculation of permissible values to estimate the performance of machines for pre-sowing treatment of seeds.

To assure the quality of technological processes involved in the preparation of seeds for sowing, it is necessary to identify their quantitative estimates.

Proceeding from the above-mentioned requirements and provided that the studied processes are random variables with the properties of stationarity and ergodicity, tolerances $\pm\Delta_x$ on their time duration can be used as such estimates.

The probability of maintaining tolerance (quantitative assessment of the quality of processes during pre-sowing treatment) is defined as:

$$P_\Delta = \int_{-\Delta_x}^{+\Delta_x} f(x)dx, \quad (8)$$

where $f(x)$ is the distribution density of the parameters x.

The distribution of these parameters differs from the normal one, but calculating the acceptable values of the quality of technological processes and the pre-sowing treatment, their distribution can be considered normal. With such a distribution pattern of parameters,

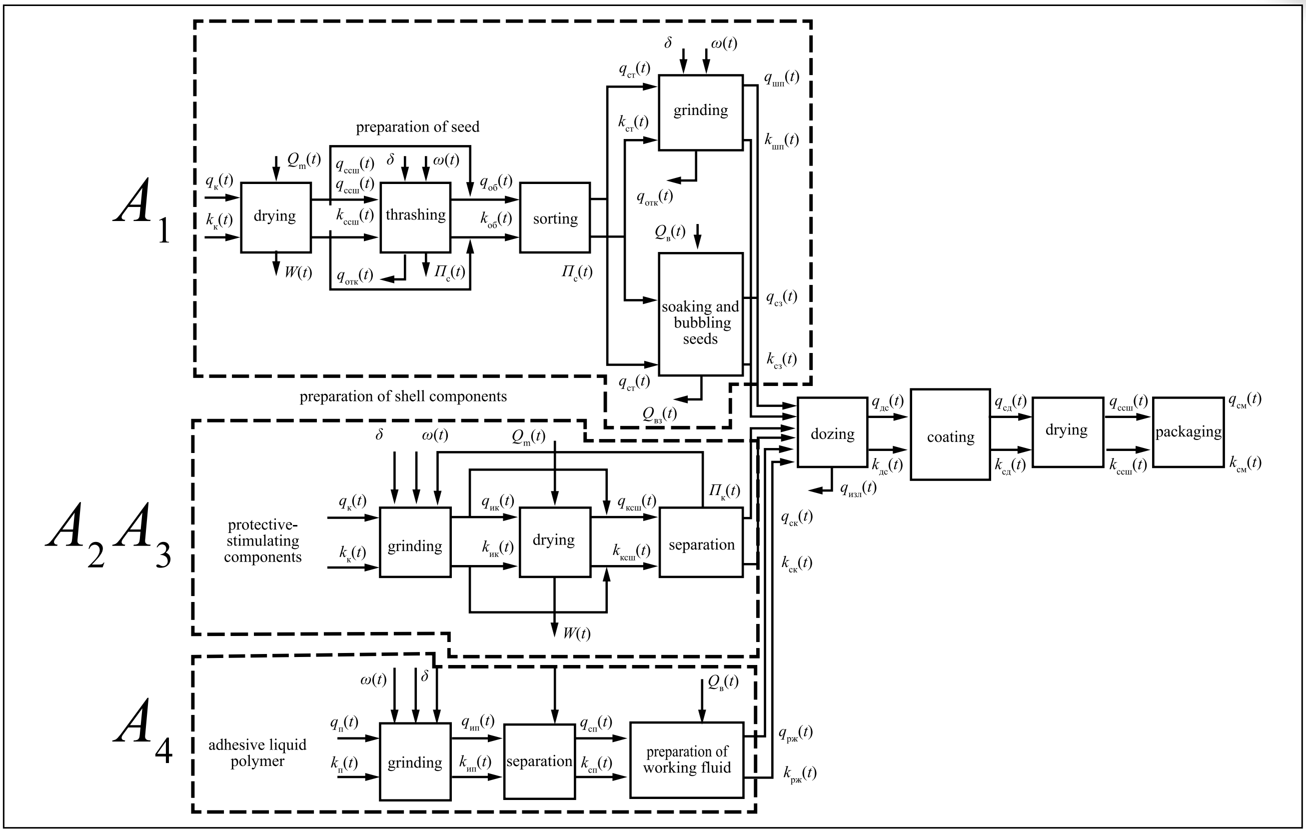

Fig. 5. Model of functioning of technological process of drawing artificial covers

relation (8) is reduced to the form:

$$P(-\Delta x < x < +\Delta x) = \Phi\left(\frac{\Delta x - m_x}{\sigma_x}\right) - \Phi\left(\frac{m_x - \Delta x}{\sigma_x}\right), \quad (9)$$

where $\Phi(x)$ is the Laplace function,

$\frac{\Delta - m_x}{\sigma_x}$ – the normalized value of the argument.

With a symmetrical deviation of $\pm\Delta_k$ relative to the mean value of m_x, the possibility of developing an evaluation of the process quality with a probability P in the interval $\pm\Delta_x$ is determined as follows: if the interval Δ_{x1} and Δ_{x2} is symmetric with respect to the scattering center and $\Delta_{x1} = m_x - \Delta_x$, and $\Delta_{x2} = m_x - \Delta_x$, formula (9) takes the form:

$$P\left(|x - m_x| < \Delta_x\right) = \Phi\left(\frac{\Delta_{x1}}{\sigma_x}\right) - \Phi\left(\frac{\Delta_{x2}}{\sigma_x}\right), \quad (10)$$

and since $\Phi(k)$ is an uneven function, the equation will have the form:

$$P\left(|x - m_x| < \Delta_x\right) = 2\Phi\left(\frac{\Delta_x}{\sigma_x}\right) \quad (11)$$

or

$$P\left(|x - m_x| < \Delta_x\right) = 2\Phi\left(\frac{\delta_x}{v_x}\right), \quad (12)$$

where Δ is the functional tolerance for deviation,

$$\delta_x = \Delta_x / m_x - 1 \left[(\Delta_x - m_x) / \sigma_x = \frac{m_x\left(\frac{\Delta_x}{m_x} - 1\right)}{\sigma_x} \right],$$

the relative diameter of the pellets obtained, expressed in %;

$v_x = \left(\sigma_x / m_x\right)$ – the coefficient of variation.

Here m_k is the average value of the diameter of the obtained pellets, *mm*, (as a measure of the quantitative evaluation of the technological process quality).

Conclusions

The criterion for optimizing the processes for pre-sowing seed treatment will be the probability of maintaining the tolerance for this process, therefore, the higher the probability of maintaining the tolerance is, the more stringent technological requirements must be met by the entire technological process of pre-sowing seed treatment and the performance quality of each machine.

Expressions (11) and (12) have been used to determine the probability of maintaining the specified tolerances $\pm\Delta_x$ from the results of experimental studies of the processes of artificial coating after determining their numerical characteristics-the mean value of m_x and the standard deviation m_x and calculating their acceptable values for a given value of δ_x.

Due to the statistical nature of the processes of pre-sowing seed treatment under conditions of normal functioning of machines and equipment, , the average values of these parameters were calculated to estimate the parameters taking into account the validity and reliability of the characteristics obtained.

After making limitations on P_{Δ}, the obtained characteristics have been used to determine the acceptable values in view of agrotechnical requirements for pre-sowing seed treatment and the quality of machinery and equipment.

Taking into account the above-mentioned conclusions, the criterion for increasing the efficiency of technological processes in the application of artificial casings should be an increase in the probability of maintaining the tolerance $P(\Delta) \Rightarrow max$ of the quality indices of technological processes, namely, the angle of friction and seed supply; concentration and supply of adhesive liquid; granulometric composition and supply of protective-stimulating components; pneumotransporting speed of protective and stimulating components; kinematic mode of the deposition of artificial coatings.

The disaggregation of the structural model of the technological process of pre-sowing seed treatment (Fig. 2) into components (Fig. 4 and 5) has allowed to establish a set of technological processes; the quantitative characteristics and dynamics of their flow significantly affect the process of pre-sowing seed treatment as a whole. This set includes the following processes: preparation of seeds, adhesive liquid, protective-stimulating components and fillers, as well as ensuring their interaction with the purpose of their layering and coagulation to form an artificial coating.

REFERENCES

1. Modelirovaniye sel'skokhozyaystvennykh agregatov i ikh sistem upravleniya [Modeling of agricultural units and their control systems] /Ed. by A.B. Lur'ye. L.: Kolos. 1979. 312. (In Russian).
2. Valge A.M., Pashchenko F.F. Matematicheskoye modelirovaniye tekhnologicheskikh protsessov sel'skokhozyaystvennogo proizvodstva po eksperimental'nym dannym (Dinamicheskiye modeli): Metodicheskiye rekomendatsii [Mathematical modeling of technological processes of agricultural production according to experimental data (Dynamic models): Guidelines] NIPTIMESKH NZ RSFSR. L.: Pushkin, 1980. 85. (In Russian).
3. Valge A.M. Obrabotka eksperimental'nykh dannykh i modelirovaniye dinamicheskikh sistem pri provedenii issledovaniy po mekhanizatsii sel'skokhozyaystvennogo proizvodstva [Processing of experimental data and modeling of dynamic systems during research on agricultural production mechanization]. SPb.: SZNIIMESKH, 2002. 176. (In Russian).
4. Yenikeyev V.G., Kerber V.N., Kryachko K.A. Polucheniye pervichnoy informatsii i yeye obrabotka dlya modelirovaniya sel'skokhozyaystvennykh agregatov i ikh sistem regulirovaniya [Generation and processing of primary information for the simulation of agricultural machines and their control systems] //Zapiski LSKHI. L., 1966. Vol. 108. Issue 1: 41-46. (In Russian).
5. Yenikeyev V.G., Valge A.M., Plaksina Ye.G. Ispol'zovaniye statisticheskikh metodov dlya obrabotki dannykh pri provedenii nauchnykh issledovaniy po mekhanizatsii i elektrifikatsii sel'skokhozyaystvennogo proizvodstva [Use of statistical methods for data processing in conducting a scientific research on the mechanization and electrification of agricultural production]. L., 1978. 64. (In Russian).
6. Kubeyev Ye.I. Optimizatsiya kinematicheskogo rezhima drazhirovaniya [Optimization of the kinematic mode of pelleting] // *Agrarnaya nauka*. 2010. 7. 29-30. (In Russian).
7. Kubeyev Ye.I. Vzaimodeystviye semyan i komponentov drazhe [Interaction of seed and pellet components] //*Tekhnika v sel'skom khozyaystve*. 2010. 3. 37-39. (In Russian).
8. Kubeyev Ye.I. Uvelichit' vskhozhest' semyan morkovi [Incresing the germination rate of carrot seeds] // *Sel'skiy mekhanizator*. 2010. 8. 16-17. (In Russian).
9. Kubeyev Ye.I. Veroyatnostnaya otsenka kachestva kalibrovaniya drazhirovannykh semyan ovoshchnykh kul'tur [Probabilistic assessment of the calibration quality of pelleted vegetable seeds] //*Mekhanizatsiya i elektrifikatsiya sel'skogo khozyaystva*. 2010. 4. 26-27. (In Russian).
10. Chernoivanov V.I., Ezhevskiy A.A., Fedorenko V.F. Mirovyye tendentsii mashinno-tekhnologicheskogo obespecheniya intellektual'nogo sel'skogo khozyaystva [Global trends in machine-technological support of intellectual agriculture]. Moscow: Rosinformagrotekh. 284. (In Russian)
11. Tariq Shah, Amir Zaman Khan, Asif ur Rehman, H. Akbar, A. Muhammad, S.K. Khalil. Influence of pre-sowing seed treatments on germination properties and seedling vigor of wheat // Research in: Agricultural & Vet. Sci. 1(1): 2017. 62-70. (In English)

The paper was submitted to the Editorial Office on 01.02.2018 The paper was accepted for publication on 09.04.2018

Conflict of interest. The authors declare no conflict of interest.