# Production algorithm of modified nutrition for paulownia with an increased sequestration of carbon in a carbon poligon environment using a multistage plug flow reactor

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**Abstract.** The aim of the paper was to introduce an algorithm by which a production method of any complex liquid solution can be done using a multistage plug flow reactor from "Innovative Engineering". The example given in the paper is a modified nutrition for Paulownia with an increased sequestration potential of carbon in carbon polygon environment. The multistage plug flow reactor is designed to continuously mix liquids in order to create a complex solution consistent of up to 7 components if only one reactor is used. If multiple reactors are used in connection, then it is possible to create a solution that is even more complex. The modified nutrition solution for paulownia that increases sequestration of carbon is then created using the reactor. In this work the step-by-step algorithm is given to create the nutrition solution and the efficiency comparison of the methods of using multistage plug flow reactor and traditional methods is given based upon the optimal criteria.

## 1 Introduction

Paulownia is one of the most promising tree-based plants to be used in carbon polygons environments due to its high CO2 absorption, soil recovery properties from erosion and properties to balance soil nutrition after intensive agriculture or environment pollution. The paulownia trees resistant to pests and diseases whereas the trees can grow up in two to three years [1].

To increase the sequestration of carbon by the paulownia plants a specific method of clonal microreproduction was developed by I. M. Bamatov and his colleagues [2]. The method the suggest involves an in-vitro method of getting the strongest donor plant, and reproducing it multiples times over. This allows to get genetically identical seedlings with strong survival and growing properties. After this step a specific set modified liquid nutrition (Table 1) is introduced to be used to enhance the sequestration of carbon [2].

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**Table 1.** The composition of the modified nutrient medium MS. Media concentrations (mg/l).

| № | Nutrition Components | MS Control | Variation 1 |
|---|---|---|---|
| 1 | NH4NO3 | 1650 | 1650 |
| 2 | KNO3 | 1900 | 1900 |
| 3 | MgSO4 7H2O | 370 | 370 |
| 4 | KH2PO4 | 170 | 170 |
| 5 | CaCL2 2H2O | 440 | - |
| 6 | H3BO3 | 6.2 | 6.2 |
| 7 | MnSO4 4H2O | 22.3 | 22.3 |
| 8 | ZnSO4 7H2O | 8.6 | 8.6 |
| 9 | KJ | 0.83 | 0.83 |
| 10 | Na2MO4 2H2O | 0.25 | 0.25 |
| 11 | CuSO4 5H2O | 0.25 | 0.25 |
| 12 | CoCL2 5H2O | 0.025 | 0.025 |
| 13 | FeSO4 7H2O | 27.8 | 55.6 |
| 14 | Na2-ЭDTA | 37.3 | 37.3 |
| 15 | Ca(NO3) 4 H2O | - | 112 |
| 16 | Sucrose | 30000 | 20000 |
| 17 | Agar | 7000 | 7000 |

A chemical reactor is a construction that isolates the interacting chemical reagents from the external environment and allows you to add or absorb the energy generated inside the reactor. Reactor technology was created for Chemical Reaction Engineering (CRE) research [3].

To describe and evaluate the operation of a chemical reactor, two types of ideal reactors are used: the Ideal Plug Flow Reactor (IPFR) and the Ideal Continuous Stirred Reactor (ICSR) [4, 5].

In general, flow in tubular reactors is directed in one dimension, say in the z direction. Then, the main gradients (flow velocity, pressure, convection) are also directed in this direction. If convective transport completely dominates diffusive transport, then diffusive transport can be ignored. The equations and the solution of these equations, resulting from such a designation, created such a model as IPFR. When the homogeneity of concentration and temperature due to the presence of large coefficients of dispersion, i.e. the mean square deviations, one can completely neglect the gradients in all directions and integrate all equations globally in all directions (assuming convective flows at the boundaries), one obtains the ICSR model.

Idealized reactor models give a good representation of what is happening inside the reactor, provided that there are no unintended reagents in the reactor. This makes it possible to evaluate the efficiency of a particular reactor based on the established criteria. Such criteria can be, for example, a comparison of performance and control complexity. Of course, the use of idealized reactors is not practical, since such technologies are expensive, and therefore the industry now mainly uses either simplified chemical reactors or averaged modified copies of ideal reactors.

$$\frac{dF_S}{dV} = r_s \quad (1)$$

Where $F_s = \rho_s V_s A / M_{Ws}$ (mol / s) – This dependence is the model of Ideal Plug Flow Reactor [6].

Where $M_{W_s}$ – molecalar mass of the flow at the tube boundaries, $\rho_s$ – density of the solution inside the of the reactor, A – cross section area of the reactor, $V_s$ – average velocity of the solution, $F_s$ – force onto the particles of the solution to create a flow, $r_s$ – reaction speed.

$$F_s|_{out} - F_s|_{in} = R_s V \quad (2)$$

Where this expression is called the Ideal Continuous Stirred Reactor.

Where $F_s|_{out}$- is the mixing force onto the particles at the end of the reactor, $F_s|_{in}$- is the mixing force onto the particles at the entrance of the reactor, $R_s$ – is the energy spent on mixing and V – is the volume of the reactor [7, 8].

The multistage reactor from "Innovative Engineering" represented a 6-stage plug flow reactor, where the reactor was integrated to a system that allowed mixing of the reactors content. The main mixing element is the reactor base instead of the stirrer. This allows a high degree of displacement to be maintained while maintaining a high degree of mixing in the reactor.

The control system of the multistage reactor ensured continuous operation of mixing liquid chemicals into 6 cylindrical reactor volumes at once, allowing additional reagents to be added during the mixing without interruptions in operation and allowed heating of certain reactor tubes while cooling others. The first 4 tubes were provided with a tubular heating system, the last two were provided with a cooling system. Each mixing volume is connected to the next by means of a flexible carbon fiber tubing.

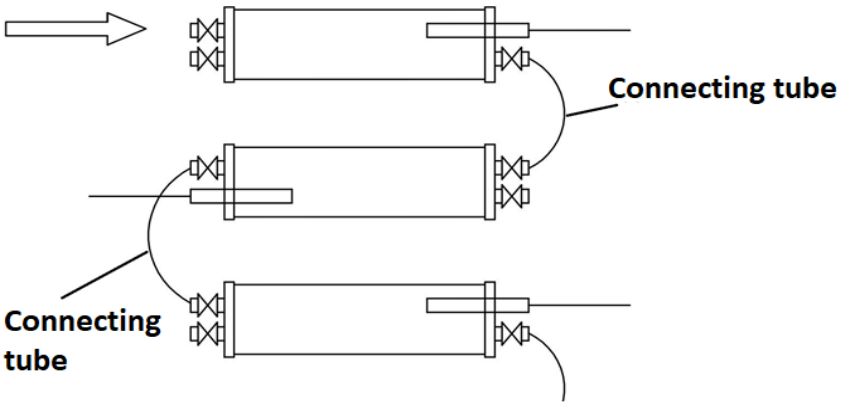


**Fig. 1.** Layout of the reactor tubes.

The process of continuous mixing of the reagents is ensured, in other words, even when we add a new reagent to the liquid mixture in the reactor, the mixing process could be continued. At the end of each tube, two taps are placed, one for connecting to other tubes, the second for pouring reagents. It turns out as a checkerboard pattern when the tube is connected on one side with the other tube of the previous one, and on the other with the tube of the next one, together with a tap for filling reagents.

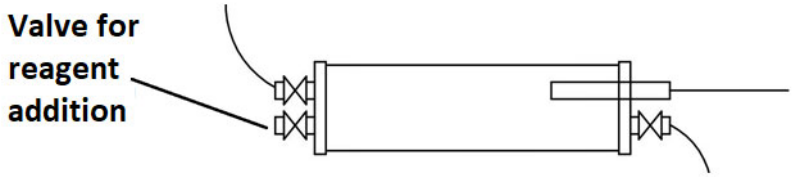


**Fig. 2.** Scheme of adding reagents to the reactor tube.

The thermosensory system is designed as follows. At the entrance to the tube, next to the connecting hydrocarbon hose with the previous tube of the reactor, a space was provided for placing thermosensors in the tube. The sensors send information to the information processing receiver for a selective period of time set by the operator. The receiver stores this information for a certain period of time, which is set to one hour by default, and can be changed by the operator.

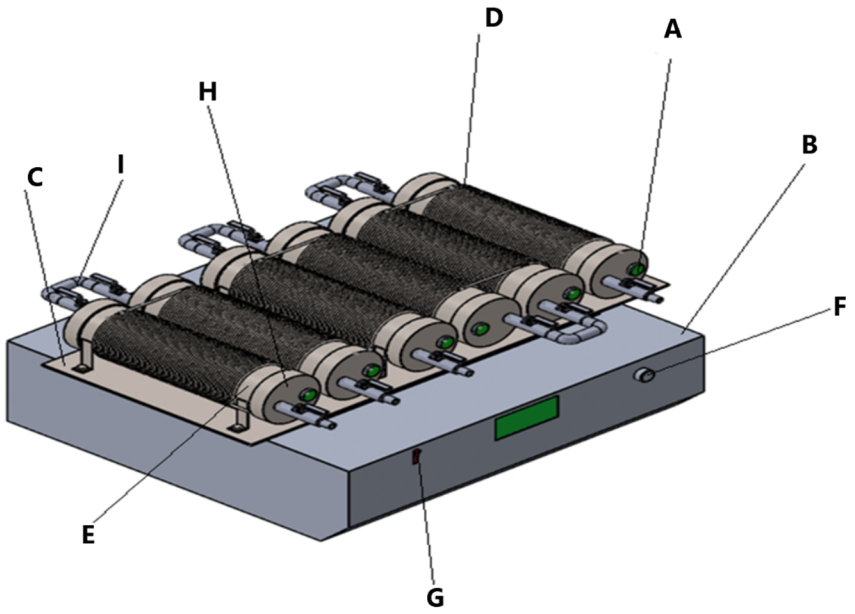


**Fig. 3.** Element configuration of a multi-stage reactor for continuous mixing of liquids. Where **A** is the input of the temperature sensor into the tube of the platform for monitoring the temperature regime. B is the reactor platform case. C is the reactor oscillatory platform. D is the copper line of the heating/cooling system. E is the clamp for fastening the mixing volumes to the reactor base, F is the control wheel of oscillations in the base of the reactor. G - button for turning on and off the reactor, H - reactor tubes with a developed design of the reactor covers, I - carbon fiber hose for connecting the reactor tubes to each other, giving 6 stages of mixing to the reactor.

The presented in Figure 4 plug flow reactor can be used to produce the modified nutrition (Table 1) for paulownia with an increased sequestration of carbon. The usage of the reactor can significantly reduce the difficulty of the production due to multistage liquid mixing properties. This allows to get a solution that has the necessary composition of the nutrients

and other chemicals in appropriate proportions. The question that is still to be answered is the algorithm by which this can be achieved [3, 9].

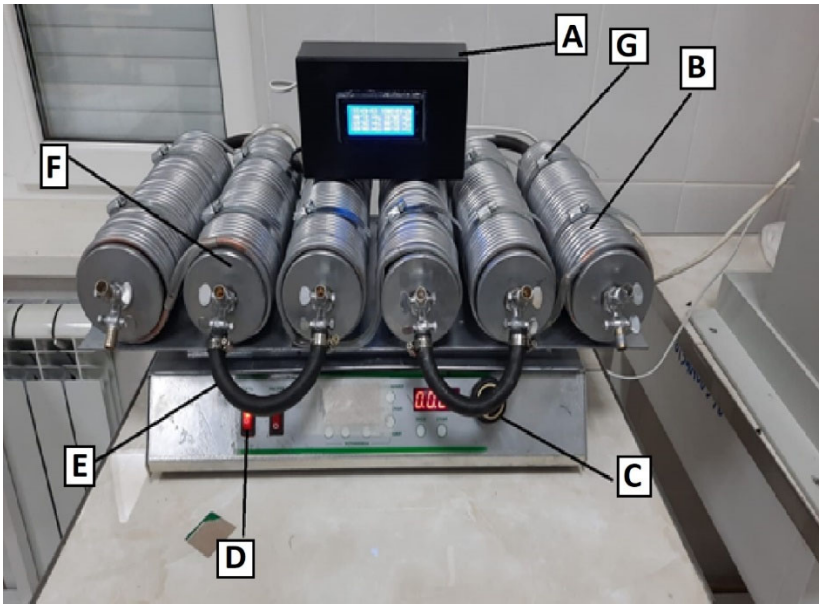


**Fig. 4.** A multi-stage plug flow reactor for continuous liquid mixing.

## 2 Results and discussion

The production algorithm for the modified nutrition of paulownia with increased sequestration of carbon is necessary in order to optimize the usage of multistage reactor. The algorithm we are suggesting is based on the following criteria:

1) Reduced energy consumption.
2) Reduced live time
3) Increased automation
4) Continuous mixing

The criteria above gives a framework according to which we can develop the production algorithm. This means that the production process for the modified nutrition is done as fast as possible wasting the least amount of energy and is done automatically and continuously after the initial setup done by the operator.

The actual algorithm is as follows:

1) Turn on the heat supply
2) Turn on the heating / cooling system of all tubes.
3) Set up the temperature conditions for each tube.
4) Determine the temperature regime for each reactor tube, taking into account the heat transfer coefficient from the furnace to the reactor, the mathematical model for calculating the final temperature in the reactor tube itself, and the reagent supply rate.
5) Open the reagent addition valve of all tubes of the reactor.
6) Turn on the periscope suction pump on the hydrocarbon hose (or place the tank higher than the reactor).
7) Add the required amount of liquid to the reactor tube regulating the proportions using the valve.

8) Wait until the desired temperature inside the reactor tube is reached by monitoring the temperature with a thermosensor system.
9) Open the reagent addition valve, add the second reagent.
10) Start the oscillatory movement of the reactor base (stirring)
11) Wait for the complete mixing of the reagents and the achievement of the desired physical and chemical properties of the final liquid inside the reactor
12) If you need to add 3, 4 ... reagents, repeat steps 5 to 8.
13) Pour the required amount of liquid mixture from the first tube into the second tube of the reactor under pressure from the pump.
14) Repeat steps 6 to 13 for subsequent operations with the rest of the reactor tubes
15) …
16) …
17) Pour the finished liquid into the dishes.

The final modified nutrition (the composition is can be seen in table 1) we get is as can be seen in Figure 5 a liquid solution used to increase the sequestration of carbon potential to be used in carbon polygon environment.

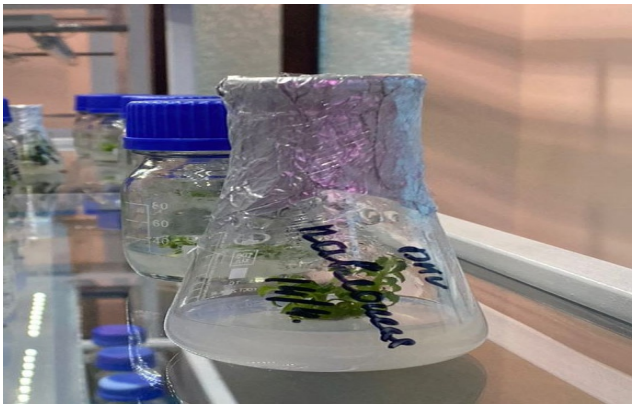

**Fig. 5.** Liquid solution for the paulownia sequestration increase.

The suggested algorithm allows us to create the solution in less than an hour compared to traditional 4-5 hours. This allows the increase of production speed as well as the quality of the final product.

## 3 Conclusion

The aim of the work was the introduction of a modified nutrition production algorithm for paulownia plant that increases the sequestration potential of the tree. The production is done using a multistage plug flow chemical reactor for continuous liquid mixing. The reactor has a property that allows a 6-stage mixing of different liquid solutions if only one reactor is used, and if used in connection of multiple reactors, then with each reactor additional 6 stages are added. This allows the creation of any liquid solution of any difficulty. The heating and cooling stages allow separate endothermic and exothermic reaction to take place in one single reactor. The final production algorithm is consisting of 16 steps that should be taken in numerical order. In less than one hour, at least 8 liters of final solution can be produced against 1 liter per 4 hours using the traditional way.

## References

1. Xiaoke Wang, Zongwei Feng, Energy **20(2)**, 117-121 (1995). ISSN 0360-5442. https://doi.org/10.1016/0360-5442(94)00057-A
2. I. M. Bamatov, Innovative technology of clonal microreproduction in expanding the biodiversity of food plants (PhD thesis) (Mountain State Agrarian University, 2020)
3. I. M. Bamatov, D. M. Bamatov, IOP Conference Series: Earth and Environmental Science **537(3)**, 032020 (2019)
4. Pю Watts, C. Wiles, Journal of Chemical Research. April, 181-193 (2012). https://www.doi.org/10.3184/174751912X13311365798808
5. A. Donoso-Bravo, C. Sadino-Riquelme, D. Gómez, C. Segura, E. Valdebenito, F. Hansen, *Modelling of an anaerobic plug-flowreactor*. Process analysis and evaluation approaches with non-ideal mixing considerations. Bioresour.Technol **260***,* 95-104 (2018)
6. E. Rossi, I. Pecorini, P. Paoli, R. Iannelli, J. Environ. Chem. Eng. **10**, 106963 (2022)
7. S. Li, Tank Reactor, Reaction Engineering*,* 95-160 (2017)
8. G. Towler, R. Sinnott, Chemical Engineering Design: Principles, Practice and Economics of Plant and Process Design. 2nd ed. Boston: Elsevier (2013)
9. I. M. Bamatov, D. M. Bamatov, M. M. Arsanov, IOP Conference Series: Earth and Environmental Science **677(4)**, 042027 (2021)