BIOPROCESS ENGINEERING

VISUAL BASIC FOR APPLICATIONS AS A TOOL FOR AUTOMATING MATERIAL BALANCES IN A BIOPROCESS PLANT

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ABSTRACT

A material balance represents a fundamental application of the principle of conservation of material, employed in the meticulous analysis of an industrial plant. The present work aims to provide an automated solution for calculations involving material balances in a downstream section of a bioprocess plant through mathematical modeling and simulation. For this purpose, an application was developed using a programming language Visual Basic for Applications (VBA) in MS Excel®. This application allows for the automation of calculations, optimizing time and minimizing errors associated with manual execution. It is concluded that the use of this application provides a valuable tool for students and professionals of the Bioprocess Engineering, simplifying process analysis and contributing to greater operational efficiency.

Keywords: Material balance. Excel. VBA. Graphical interface. Bioprocess plant.

1 INTRODUCTION

Material balances are fundamental in Bioprocess Engineering, involving quantitative analyses that describe the flow of mass within process units, including input, output, consumption, reaction, and accumulation rates, following the principles of mass conservation by Lavoisier. To solve these balances and understand the systems in question, it is crucial to formulate appropriate mathematical equations or systems (BORGES, 2018). Naturally, these procedures become excessively iterative and time-consuming, thereby escalating the potential for errors to proliferate. Consequently, the utilization of software and computers becomes paramount in simplifying and automating material balance resolutions.

In the Industry 4.0 era, where automation is fundamental, the development of automated calculation tools in MS Excel® has become crucial. This approach not only increases efficiency but also improves the accuracy of results, contributing to more informed decision-making and more effective experiment planning (MOTA et al., 2021).

The intersection of engineering and technology has propelled significant advancements in the industry. The use of software and automation tools simplifies routine tasks, such as material balances calculations, which are essential for modeling complex processes like biofuels or biochemicals production. This integration of technology not only enhances efficiency but also fosters innovation and continuous progress in the field, underscoring the importance of adapting to the latest technological trends to drive societal advancement (SILVA, 2022).

With the aim of automating calculation execution and promoting the adoption of new technologies, this work proposes the development of a Graphical User Interface (GUI) through the creation of routines using the Visual Basic for Applications (VBA) programming language of MS Excel® software. Part of a downstream section of a bioprocess plant was involved. This approach aims to enhance the usability and efficiency of available tools.

2 MATERIAL & METHODS

This work aims to provide an automated approach to calculating material balances. Thus, the general expression guiding the material balance process can be qualitatively described by Equation (1). Before performing the balance, it is crucial to define the system boundaries, thus creating a control volume in which the inputs and outputs will be analyzed. All procedures were conducted in the VBA programming environment within the MS Excel® application, which is part of the Office 365 Suite in the 2021 version. The equipment used comprised a HP laptop, specifically the Intel Celeron model, equipped with an Intel® Celeron® CPU 1000M @ 1.80GHz 1.80 GHz processor, 4 GB of RAM, and a 500 GB hard drive. The operating system adopted was Windows® 10 Pro.

$$INPUT - OUTPUT + REACTION = ACCUMULATION \tag{1}$$

The first stage of this work involved mathematical modeling, which entailed identifying the equations that describe the current case. To achieve this, material balances were performed, both globally and for individual components, across different control volumes. Those calculations were based on the general material balance equation given by Equation (1), which analyzes rates. No reactions occurred in the process, and that it operated under steady-state and isothermal conditions.

The second stage focused on developing the GUI on VBA/Excel®. During this phase, the design of the interfaces consumed the most time, as the programming itself mainly involved incorporating the equations derived from the material balances so that the application could display the required variables.

3 RESULTS & DISCUSSION

The main menu of the application when opening the Excel file is shown in Figure 1.
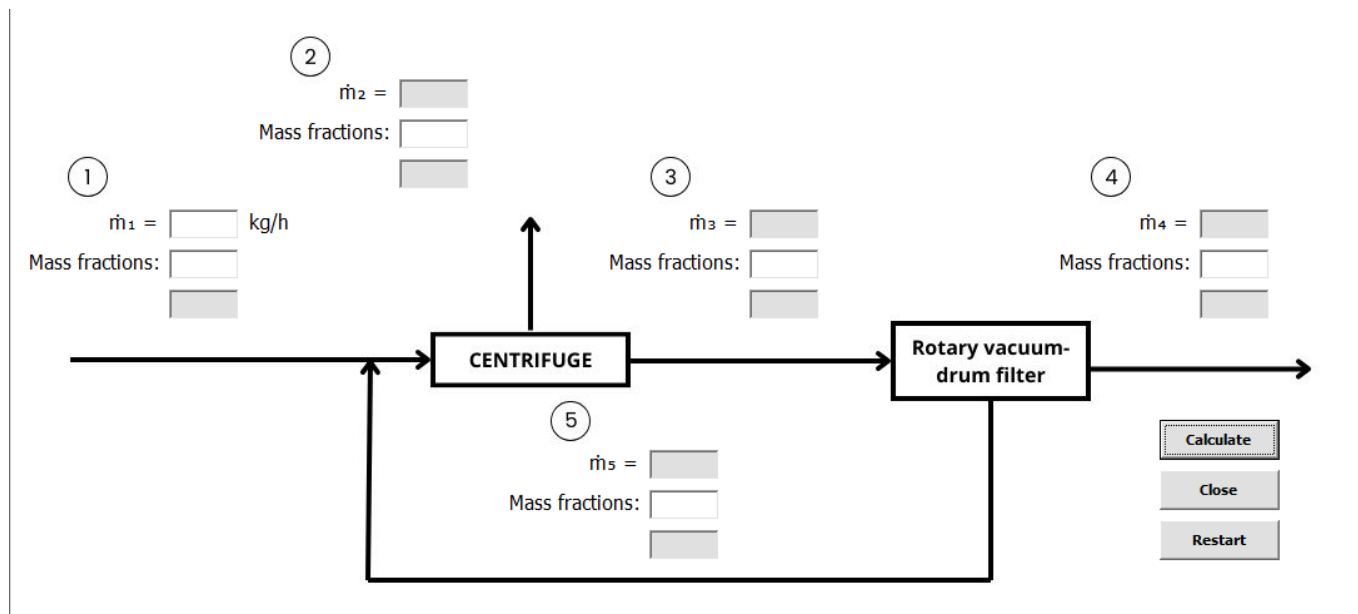

Figure 1 Graphical user interface of the application

This application features an intuitive and efficient GUI for performing material balance calculations. Upon opening the program, users have access to a main menu offering text boxes to configure the variables according to their needs. The main purpose is to calculate the mass flow rate of streams 2, 3, 4 and 5 shown in Figure 1.

The users have the option to define a generical species of interest in stream 1 and specify the stream mass flow rate there. Additionally, they have the option to define the mass fraction of this species in any stream, with the first box always referring to the species of interest and the second referring to water (binary solution). The white boxes are input data and the gray boxes are output data. After entering the necessary data, users can click the "Calculate" button, which will automatically execute the calculations. The results are then displayed in the gray text boxes, providing users with the desired information in a clear and organized layout.

To close the program, users can simply click on the "Close" button, which not only exits the application but also closes the Excel file. Furthermore, if users wish to test new sets of data, they can click on the "Reset" button, which will clear all text boxes, allowing for the input of new information.

The Figure 2 below shows an example. It's a validation of a calculation carried out manually.
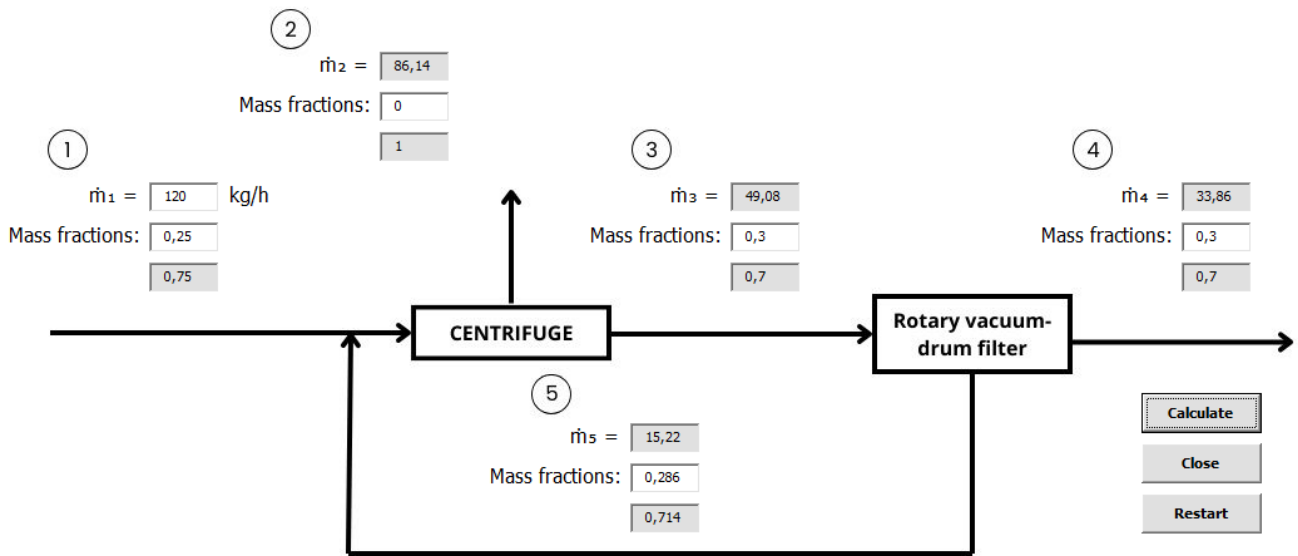
Figure 2 Graphical user interface of the application with answers

As can be observed in Figure 2, the application provides consistent values, organized in an intuitive layout. The code lines were developed based on solid theoretical principles of material balances, ensuring the accuracy and reliability of the results obtained. Its simplified graphical interface provides a pleasant user experience and facilitates the quick and precise execution of the calculations.

4 CONCLUSION

The aim of this work was to automate the calculation in the downstream section of a bioprocess plant using VBA/Excel. Recognizing the significance of user-friendly interfaces in enhancing accessibility and efficiency, the approach aimed to develop intuitive graphical interfaces. By harnessing the capabilities of code lines programmed in VBA language within the MS Excel® software environment, users were empowered with tools that promote the optimization of their works. Through this initiative, was aimed to bridge the gap between complex calculations and user-friendly interfaces, ultimately fostering a culture of technological innovation and efficiency in computational processes, mainly in an Industry 4.0 era.

The resulting application proved to be effective in solving material balance problems and automating repetitive calculations. By providing a streamlined solution, it enhances productivity and reduces the likelihood of errors inherent in manual calculations. Furthermore, this tool not only simplifies the analysis process but also demonstrates the feasibility of integrating advanced technologies to improve the efficiency and accuracy of operations performed. Its success highlights the potential benefits of incorporating innovative solutions into traditional workflows, paving the way for enhanced performance and productivity in various domains.

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