Partnership with Aerospace Institution and Biotechnology Research in Microgravity gather Engineering Students in Multidisciplinary Project

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Abstract: Research in biotechnology, at the Chemical Engineering Department at FEI – Faculdade de Engenharia Industrial, has recently focused its attention on the microgravity effect on enzymatic reactions, such as invertase and lipase, which are important for industrial applications. Several experiments have already flown, thanks to a partnership with CTA /IAE-Institute for Aeronautics and Space. Chemical Engineering undergraduates have participated in the enzyme project as part of their activities in the Student Scientific Initiation Program, and as a complementation to the discipline "Industrial Biochemistry". In order to fly the enzyme payload on board the rocket VS-30, the development of MLMD-Microgravity Liquid Mixing Device was necessary. The apparatus was designed with the participation of professors and students of the Departments of Mechanics, Electronics and Chemistry. The MLMD has three cavities, with a small chamber for invertase biochemical reaction. The small device was controlled by an electronic circuit specially designed for the purpose and implemented on a microchip. The circuit should monitor altitude and time variables, among other signals, and should start the process by injecting sucrose in the enzyme chamber, upon reaching microgravity, and dinitrosalicylic acid to inhibit the reaction, on its leave. The apparatus, which should resist vibrations, g-force, with proper sealing and electromagnetic protection, was submitted to severe tests, including parabolic flights. The MLMD flew successfully and the enzymes' experiment was analyzed by a team of professors and students. The interaction of different departments allowed students to acquire not only a technical and broad view of the problems involving a project in real life, but also an understanding of people interaction, considering different skills and background. It gave the participants the necessary training to work as a team to reach a common goal.

Keywords: microgravity, enzymes, biotechnology, payload, multidisciplinarity,

1. Introduction

Research in biotechnology has been carried out for quite a long time at the Department of Chemical Engineering at FEI – Faculdade de Engenharia Industrial. More recently a group of professors has started working in a program that studies the effect of microgravity on enzymatic reactions, such as invertase and lipase. Both enzymes are important for industrial applications, mainly for pharmaceutical and food industries. Biotechnology is a multidisciplinary science, and research in microgravity environment opens new fields for engineering applications and courses.

The research program in microgravity environment has already flown several experiments, thanks to a partnership with CTA /IAE-Institute for Aeronautics and Space, from the Brazilian Aeronautics Command. Scientists at IAE have a long international experience in this field, and are responsible for the design, development, implementation and launching of mid-range rockets VS and VLS for sub-orbital missions, which can carry scientific and technological payloads.

They have recently opened the possibility to carry civil scientific and technological experiments from universities as payloads aboard VS and VLS family rockets, and a partnership has been established with FEI, so as to develop supporting instrumentation equipment, which will be also used by other institutions, besides flying biotechnology experiments in microgravity.

Undergraduate students of Chemical Engineering have participated in the enzyme project as part of their activities in the Scientific Initiation Program for Students, and as a complementation to the discipline "Industrial Biochemistry".

2. Biotechnology in Microgravity

Research in biotechnology, at the department of chemical engineering, is focused on industrial processes related with production, purification and use of enzymes. Enzymes are proteins that act as biological catalysts and take part in most chemical reactions in all kind of cells. Different of traditional chemical catalysts, enzymes catalyse reactions under mild conditions, generally neutral aqueous solutions, room temperature and atmospheric pressure. Two enzymes are being studied: lipases, and invertase.

Lipases (triacylglycerol hydrolase EC 3.1.1.3) are enzymes that catalyse the hydrolysis of triglycerides and produces a mixture of fat acids and alcohol. This class of enzymes had an increase of interest due to its potential application on pharmaceutical field during the separation of isomers in drugs racemic mixtures. For this enzyme the immobilization on silica support and efficiency in bioreactors have been studied.

Invertase (β-fructofuranosidase E.C.3.2.1.26) is an enzyme that catalyses the hydrolysis of sucrose into a mixture of reducing sugars, fructose and glucose. Among lots of applications, great industrial importance has the production of fructose syrups from sugar cane, beet or molasses. The purpose of research on invertase is the development of bioreactors containing *Saccharomyces cerevisiae* cells.

In this biotechnological research line, experiments in microgravity environment have been performed by sending enzyme samples in space flights. Microgravity comes up as a new environment for a different type of research, in all scientific fields, especially in Biotechnology. Many works on protein crystal growth [1], cells and tissues cultures, downstream processing and others, related with medical and pharmaceutical applications, have being exploited in microgravity conditions. It is considered that there is microgravity when gravity acceleration is less than $10^{-3}\,g$. This reduced gravity environment is quite suitable for the research of the phenomena that are affected by gravity, such as fluid behaviour and mass and heat transfer [2].

Three scientific experiments in microgravity [3] were performed with the participation of chemical engineering undergraduates. The first was aboard the Space Shuttle Discovery, under STS-95 NASA Mission, in October 1998, and studied the microgravity effect on olive oil hydrolysis by immobilized lipases. The other two were performed aboard the Brazilian VS-30 rockets .One of them, on São Marcos Mission, in march 1999, studied the stability of oil water emulsion for future lipases experiments. The third one was performed on Lençois Maranhenses Mission, in February 2000, and it studied the invertase kinetics as to sucrose hydrolysis. Since sucrose has to permeate a cell membrane to reach the enzyme the study intends to verify if there are significant differences in kinetic parameters in microgravity

In order to fly the enzyme payload on board the rocket VS-30, which would remain about 200 seconds in microgravity, the development of an apparatus, MLMD-Microgravity Liquid Mixing Device, to hold liquids, so that the biochemical reaction might occur when the payload entered microgravity and stopped on its leave, was necessary. This led to an interdepartmental project.

3. MLMD – Microgravity Liquid Mixing Device

The MLMD (Fig. 1, 2) had to meet certain requirements imposed both by the biochemist scientists and the launching and flight conditions. Three liquids should be sent separately, that is the enzyme invertase for reaction, and sucrose and dinitrosalicylic acid, to promote and to stop reaction, respectively, in microgravity. The reaction should happen during a very well known period of time (Fig.3), so that its results might be compared to those of a similar experiment, which would be done on earth at the biotechnology lab, for the same period of time. Besides this, transient conditions, such as vibrations and g-force, should be avoided, to perform the experiment in normal conditions, when compared to the similar one on earth.

The MLMD had to permit that the mixture of liquids would take place only upon reaching microgravity, aboard a sub-orbital rocket, according to a pre-established flight program. The environment of the operation is severe and the device would be subjected to high thermical variations, vibrations and shock. The device should have a very low weight, high reliability, programmability and low power consumption.

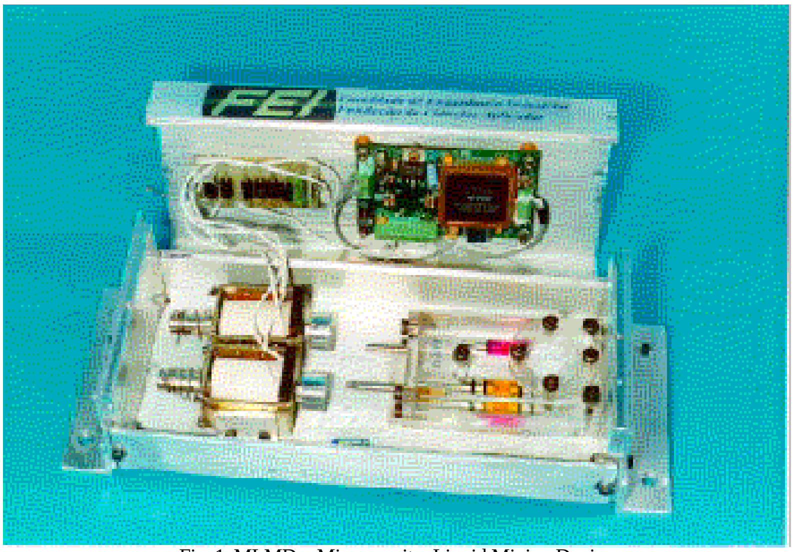

Fig. 1. MLMD – Microgravity Liquid Mixing Device

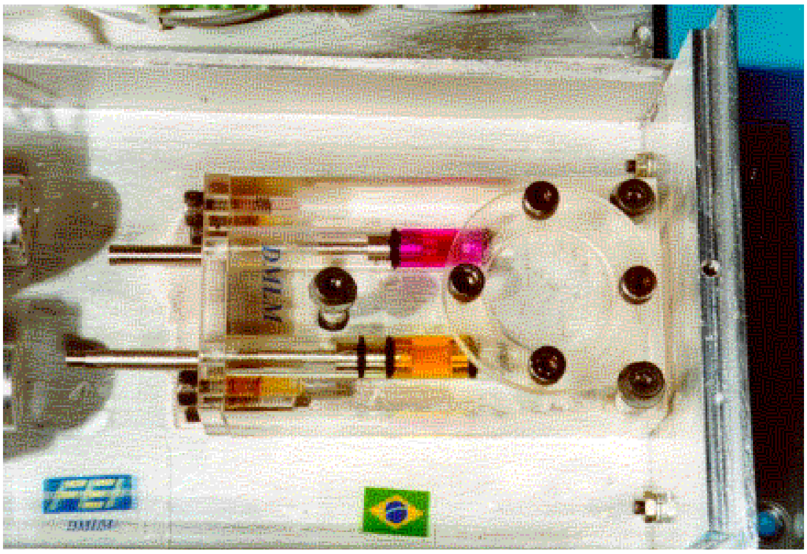

Fig. 2. Details and Internal Vision of MLMD

The apparatus, with proper sealing and electromagnetic protection as a whole, should be as small as possible, besides having a small weight, and should be resistant to vibrations and g-force. It finally turned out to be a 10x10x5 cm3 box, weighing no more than 150 g.

The MLMD was designed to have three cavities: one, a small chamber suitable for biochemical reactions, should containing the invertase enzyme, and the other two were intended to contain sucrose and the dinitrosalicylic acid, which would be used to start and to stop the biochemical reaction. Each of the liquids would be injected, at a proper time, into the main chamber, by means of an electronically controlled piston. This, in turn, would be activated by a solenoid, excited by a signal received upon entering microgravity, to start the biochemical reaction, and by another, to stop it, on its leave.

For this project, three departments were involved, at FEI, namely, Biotechnology, which determined their needs, Mechanics, which designed and implemented the way to promote the mixture and to interrupt the reaction in the micro-chamber, and finally Electronics, responsible for the design and implementation of a dedicated microchip, capture of signals, sensoring, timing and control [4,5,6].

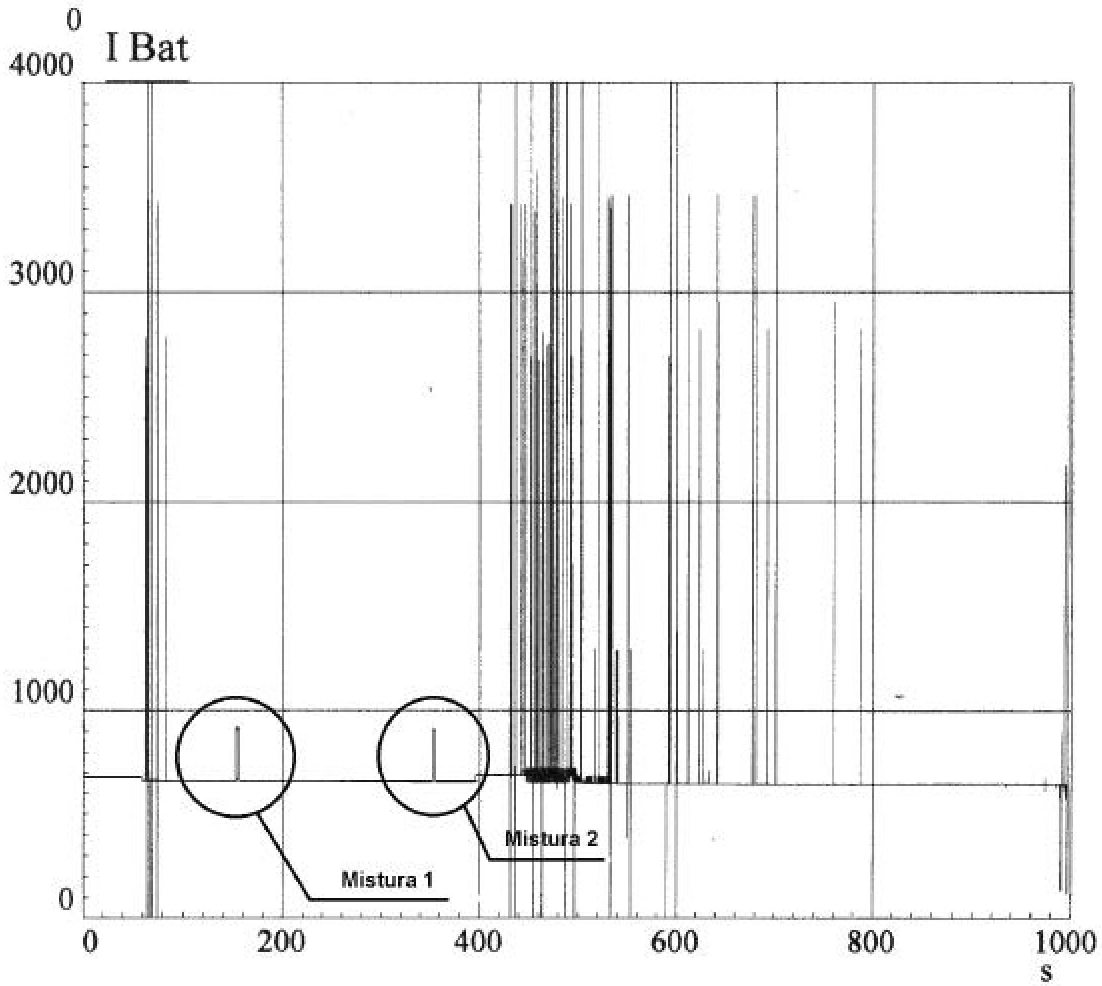

Fig. 3. Signals to start and stop biochemical reaction, detected by telemetry

Engineers at IAE/CTA were also very actively involved, both providing important technical data and information about the flight and launching conditions, and helping with test equipment .In fact they were invaluable for the project critical analysis and final tests, which would only be feasible at IAE lab facilities. The intelligent part of the MLMD was implemented on a programmable chip, EPLD Altera Max 7128, with SMD mounting, which was also responsible for the activation of small solenoids to act onto steel emboli.

The special designed microchip [7] had to monitor such variables as altitude and time, among other signals, and should start the process by injecting sucrose in the enzyme chamber, upon reaching microgravity, and the other liquid to inhibit the reaction, on its leave. The electronic project was implemented with the aid of the CAE software Max Plus II 9.21, which is composed of a Compiler, Fitter and Configurator. This software is being used at FEI under a partnership program with Altera Corporation, a major programmable chips and CAE software vendor.

The apparatus was submitted to several and severe tests. In special vibrations' lab and parabolic flights on a plane. A part of them were made aboard a Brazilian Air Force plane, on parabolic flights, in cooperation with IAE/CTA, especially intended to check for leakage, performance with vibrations and solenoids behavior. Other tests were carried out at IAE and INPE-National Institute for Space Research special labs, where it was possible to simulate launching conditions, such as vibrations and 10g-force.

4. Conclusion

The MLMD device flew successfully on board the VS-30 rocket, launched at IAE facilities, Alcântara, MA, which is located two degrees under the equator, and the enzymes' experiment was analyzed by a team of professors and students. The Industrial Biochemistry discipline was particularly benefited with the experiment, because it could apply its theory in a high-tech and real life project and its results could feedback teachers and students to enrich theory and lab practice. Other disciplines, like Digital Systems, Industrial Electronics and Mechanical Devices were also benefited and students could new and unconventional applications.

On the other hand, the interaction of different departments in this project allowed students, to acquire not only a technical and broad view of the problems which involve a project in real life [8, 9], but also an understanding of people interaction, considering different skills and background, and gave the participants the necessary training to work as a team to reach a common goal.

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