Design of a Mixing Mechanism to Prepare Hydroxypropyl Methylcellulose (HPMC) Solution to Develop Injectable Bone Graft With Desired Material Characteristics.

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Abstract

Hidroksipropil Metilselüloz (HPMC), sağlık sektöründe kemik grefti ikamesi olarak kullanılan bir polimerdir. Dikkate değer biyouyumluluğu ve toksik olmayan özellikleri nedeniyle saygı duyulan, onu çeşitli endüstrilerde yaygın olarak kullanılan çok yönlü bir bileşen haline getiren önemli bir selüloz türevi olarak öne çıkar. Bu çalışma, HPMC çözeltilerinin optimum çözünmesini ve viskozitesini elde etmekle ilgili karmaşık zorlukları araştırırken HPMC çözeltisinin hazırlanırken kullanılan manyetik karıştırıcılarla ilişkili sınırlamaları özellikle ele alır ve Hidroksipropil Metilselüloz (HPMC) karışımlarını homojenleştirmek için bir mekanik karıştırıcı geliştirmeyi amaçlar. Tasarlanan mekanik karıştırıcı, endüstriyel ölçekte üretime uygun, ayarlanabilir hız ve torka sahip olacaktır. Proje, HPMC karışımlarının üretim verimliliğini artırmayı ve sağlık sektöründe güvenilir malzemeler sağlamayı hedefler. Ayrıca, HPMC'nin sağlık sektöründeki kullanımını artırmayı amaçlayan bu çalışma, HPMC'nin özelliklerini optimize etmeye odaklanır. Geliştirilen sistem, HPMC'nin homojen karışımını sağlamak için özel bir pervane ve ileri teknoloji motor sistemlerinin entegrasyonunu içerir. Çalışmanın etki alanı, HPMC'nin farklı endüstrilerdeki potansiyel sağlık sektörü uygulamalarını gösterir.

Anahtar Kelimeler: *Hidroksipropil Metilselüloz (HPMC), Kemik Greft, Mekanik Karıştırıcı, Manyetik Karıştırıcı, Ortopedi Cerrahisi, Sağlık Sektörü, Doku Mühendisliği.*

Hydroxypropyl Methylcellulose (HPMC) is a polymer used in the healthcare industry as a bone graft substitute. Respected for its remarkable biocompatibility and non-toxic properties, it stands out as an important cellulose derivative, which makes it a versatile component widely used in various industries. This study specifically addresses the limitations associated with magnetic stirrers used in the preparation of HPMC solution while investigating the complex challenges associated with achieving optimal dissolution and viscosity of HPMC solutions and aims to develop a mechanical stirrer for homogenizing Hydroxypropyl Methylcellulose (HPMC) mixtures. The designed mechanical mixer will have adjustable speed and torque, suitable for industrial scale production. The project aims to increase the production efficiency of HPMC mixtures and provide reliable materials in the healthcare sector. In addition, this study, which aims to increase the use of HPMC in the healthcare sector, focuses on optimizing the properties of HPMC. The developed system includes the integration of a special propeller and high-tech engine systems to ensure the homogeneous mixture of HPMC. The scope of the study shows the potential healthcare sector applications of HPMC in different industries.

Keywords: *Hydroxypropyl Methylcellulose (HPMC), Bone Graft, Mechanical Mixer, Magnetic Mixer, Orthopedic Surgery, Health Sector, Tissue Engineering.*

1. Introduction

It has been observed that biocompatible polymers such as HPMC provide various advantages such as structural support, biodegradability, minimally invasive delivery to patients, adjustable viscosity and gelling in bone graft applications. This project represents an initiative aimed at expanding the functionality and scope of use of HPMC within the construction chemicals industry. We aim to integrate HPMC with an innovative mixing mechanism to enhance its applications in the healthcare sector. Our goal is to transform HPMC into a form that can be injected into bone tissue. To achieve this objective, we have designed a mixing mechanism centered around a screw shaft system. Supported by DC motors and stepper motors, this system ensures the homogeneous mixing of HPMC. This innovative approach not only seeks to enhance the therapeutic potential of HPMC in the healthcare sector but also aims to broaden its industrial applications. This report provides a detailed explanation of our project's methodology, design considerations, and the expected impact on the future applications of HPMC.

2. Materials & Methods

In optimizing the mixing process for HPMC within our project, meticulous attention has been paid to material selection and methodological development. Success relies on judicious component choices and precise execution of methods. Here, we provide a detailed account of the materials and methodology used to achieve our desired outcome.

Materials:

1. (Hydroxypropyl)methyl Cellulose (HPMC)
2. Distilled water
3. Heather
4. Beaker (500ml)
5. DC Motor
6. Ball Screw Mechanism
7. Nema-17 Step Motor
8. 3D – Printed Propeller

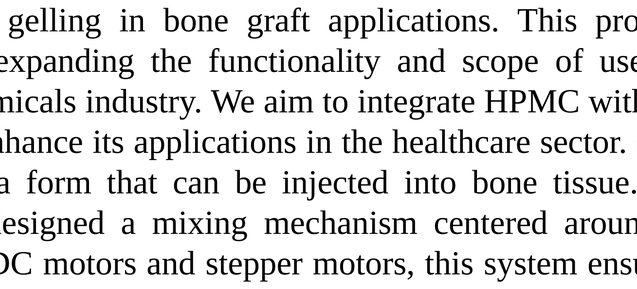

Figure 1*: Illustration of the Process by* ***BioRender***

Methods:

In the first step, we will use 500 ml volumetric beakers respectively; 0.1 %, 0.2 %, 0.3 %, 0.5 %, 0.8 %, and 1.0%. we prepared HPMC solution at concentration values. We diluted the solution with distilled water.The mixing process maintains a crucial 80-degree Celsius temperature for optimal HPMC mixture consistency. The propeller, driven by a DC motor, ensures uniform mixing. Precision vertical movement control is achieved with the Nema-17 Step Motor-powered Ball Screw mechanism, accommodating different beaker sizes. Meticulously integrated components, including Nema-17 Step motor, DC motors, Ball Screw mechanism, and 3D-printed propeller, undergo rigorous testing and calibration for seamless collaboration, resulting in an efficient HPMC mixing system.

3. Results and Discussion

Viscosity is a value measured using a viscometer device and provides information about the liquid's resistance to flow. Liquids with high viscosity flow less than liquids with low viscosity. As the concentration of solute in the solution increases, the viscosity increases.

CONCENTRATION (%)	VISCOSITY (Pa.s)
1,00	0,438
0,80	0,238
0,50	0,085
0,30	0,022
0,20	0,021
0,10	0,018

Table 1: *Concentration and Viscosity Values of HPMC*,

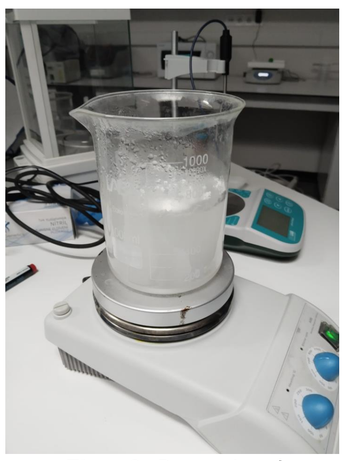

Figure 2 : *Preparation of HPMC solution with heater and magnetic mixer*

The concentration values (%) and the measured viscosity (Pa.s) We have created a calibration curve in order to examine the sensitivity and accuracy of the viscosity values. The magnetic mixer cannot mix and dissolve the HPMC polymer in distilled water due to its insufficient capacity for turnover at high concentrations. For this reason, we have confirmed that we need to prepare our solution with a mechanical mixer in order for the HPMC solution to be prepared to reach ideal conditions.

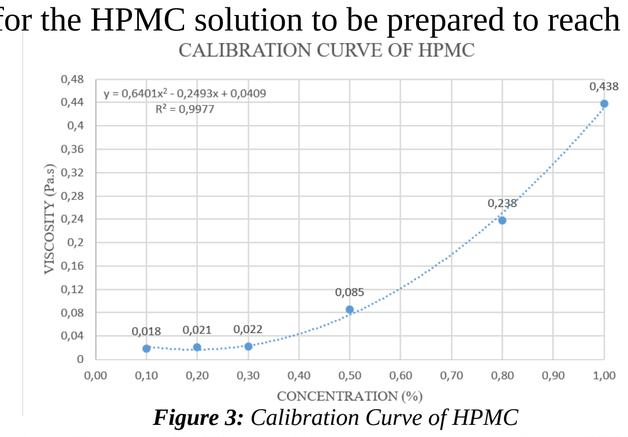

Figure 3: *Calibration Curve of HPMC*

As we mentioned at Figure 2. The calibration curve of the HPMC's R2 value was calculated as 0,9977. At the calibration curve analysis, the closeness of that parameter to 1 means the correctness of that relationship is higher. So here, the closeness of 1 is almost done, and because of that, our calibration curve is correct.

4. Conclusion

Achieving a foolproof material that dissolves clearly without any particles and has a viscosity within the acceptable range is critically important. The reason for the significance is that the choice of the viscosity level of the polymer (which is also related to the molecular weight of the HPMC) directly affects the features of the material such as emulsification, adhesion, bonding, thickening, suspension, film formation and gelation. This mechanical mixer project has provided an effective solution for the homogeneous preparation of hydroxypropyl methylcellulose mixture. The mechanicalmixer developed within the scope of the project is designed to enhance material homogeneity and optimize the mixing process. Experiments and tests have demonstrated that the mixture obtained using the mixer complies with the desired quality standards.This project offers a practical approach to more efficiently and reliably mix materials like hydroxypropyl methylcellulose in production processes within the healthcare sector. Additionally, the mechanical mixer has a broad potential for industrial applications, providing increased consistency and quality control in production processes. This study serves as a valuable reference for researchers, engineers, and manufacturers involved in material mixing in the healthcare sector.

Figure 4 : *Designed Mechanical Stirrer for HPMC*

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