

# ИНФОРМАТИКА, ВЫЧИСЛИТЕЛЬНАЯ ТЕХНИКА И УПРАВЛЕНИЕ INFORMATION TECHNOLOGY, COMPUTER SCIENCE AND MANAGEMENT



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Научная статья



## Математическая модель системы управления pH в *in vitro* модели желудочно-кишечного тракта домашней птицы

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### Аннотация

**Введение.** Существенная нелинейность химических реакций кислот и оснований определяет алгоритмы управления в режиме подкисления или подщелачивания, то есть периодической дозации минимального объема кислоты или щелочи. Такое регулирование может быть малоэффективным, т. е. допускает недостаточную или избыточную концентрацию контролируемого вещества. Статья посвящена проблеме точного регулирования водородного показателя в мини-биореакторах. Предлагается использовать цифровую модель системы управления кислотностью для подбора концентраций дозируемых растворов, определения методов регулирования и повышения точности. Цель работы — обеспечение требуемой точности регулирования pH в *in vitro* мини-модели желудочно-кишечного тракта статического типа.

**Материалы и методы.** Исходная структурная схема модели включает накопители и потоки. Она представляет собой базу для основных дифференциальных уравнений, характеризующих изменение объема и кислотности. Для корректировки показаний кислотности результирующего раствора по температуре создана статическая модель, основанная на полиномиальной аппроксимации экспериментальных данных методом наименьших квадратов. В прикладном пакете Matlab Simulink исследованы структурные элементы математической модели. На реальной системе *in vitro* моделирования искусственного желудочно-кишечного тракта домашней птицы определены переходные характеристики для подтверждения адекватности математической модели.

**Результаты исследования.** В рамках данной работы авторы создали и проанализировали нелинейную математическую модель изменения pH в биореакторе с учетом внешних управляющих воздействий. Потоки раствора соляной кислоты, раствора щелочи и слива раствора из реактора представлены как элементы дифференциального уравнения, описывающего накопление жидкости в реакторе. Для повышения точности решение доработали с учетом температурной зависимости водородного показателя. Предложена математическая модель дозирования на основе регулятора с каналами щелочи и кислоты. Полученные данные позволили генерировать объединенную модель процесса регулирования pH в биореакторе. Адекватность решения подтверждена опытным путем. В виде структурных схем показаны модели: регулятора pH, регулирования объема содержимого в реакторе и химических реакций. Сравниваются переходные процессы математической модели и реальной системы управления. Установлено, что переходные характеристики математической модели и реальной системы идентичны по времени регулирования. Относительная погрешность регулирования реальной системой составила 0,35 %, а математической модели — 0,1 %, что соответствует требуемой точности регулирования  $\pm 0,1$  pH. В виде графиков показано влияние исследованных потоков на реакцию нейтрализации.

**Обсуждение и заключение.** Предлагаемая математическая модель позволяет подобрать оптимальные методы и алгоритмы регулирования кислотности, что ускорит создание регулятора нелинейного процесса регулирования водородного показателя. В будущем эти наработки можно интегрировать в комплексную цифровую модель всего искусственного желудочно-кишечного тракта домашней птицы для оптимизации алгоритмов управления (дозации, перемешивания, периодичности и т. п.), а также аппроксимации к объектам *in vivo*.

# Sistemy I Modeli Mabovogo Obsluzhivaniia V Kommercheskoi Deiatelnosti

**Rachel S Tattersall**



## **Sistemy I Modeli Mabovogo Obsluzhivaniia V Kommercheskoi Deiatelnosti:**

The book delves into *Sistemy I Modeli Mabovogo Obsluzhivaniia V Kommercheskoi Deiatelnosti*. *Sistemy I Modeli Mabovogo Obsluzhivaniia V Kommercheskoi Deiatelnosti* is a crucial topic that must be grasped by everyone, ranging from students and scholars to the general public. This book will furnish comprehensive and in-depth insights into *Sistemy I Modeli Mabovogo Obsluzhivaniia V Kommercheskoi Deiatelnosti*, encompassing both the fundamentals and more intricate discussions.

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  - Chapter 5: Conclusion
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5. In chapter 4, the author will scrutinize the relevance of *Sistemy I Modeli Mabovogo Obsluzhivaniia V Kommercheskoi Deiatelnosti* in specific contexts. This chapter will explore how *Sistemy I Modeli Mabovogo Obsluzhivaniia V Kommercheskoi Deiatelnosti* is applied in specialized fields, such as education, business, and technology.
6. In chapter 5, the author will draw a conclusion about *Sistemy I Modeli Mabovogo Obsluzhivaniia V Kommercheskoi Deiatelnosti*. The final chapter will summarize the key points that have been discussed throughout the book. The book is crafted in an easy-to-understand language and is complemented by engaging illustrations. This book is highly recommended for anyone seeking to gain a comprehensive understanding of *Sistemy I Modeli Mabovogo Obsluzhivaniia V Kommercheskoi Deiatelnosti*.

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