

United States Department of Agriculture
Project Initiation

Project Data for Accession Number 1032463

Project Title

Harnessing Aggregates of Hydrolyzed Plant Proteins as Greener and Effective Fat Replacer in Fat-free Dairy Foods

Project Details

Sponsoring Institution National Institute of Food and Agriculture	Project Status ACTIVE
Funding Source NIFA Non Formula	Grant Year 2024
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Proposal No. 2023-10520	Multistate No. (N/A)
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Program Code [A1364] Innovations in Food Manufacturing Technologies	

Project Director

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Recipient Organization

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Performing Department

(N/A)

Non Technical Summary

With increasing awareness of sustainability and healthy diets, the development of plant protein-based fat replacers to provide softness and lubricating effects to low-fat or fat-free products has gathered significant attention. However, the production of these fat replacers is energy-intensive due to prolonged heating at high temperatures, limiting their potential for food applications. Therefore, reducing energy consumption is essential to enhance their use in foods. In this project, plant protein is partially hydrolyzed by a protease, followed by gentle heating to form aggregates as fat replacers. The physicochemical properties of the protein hydrolysates and their aggregates are characterized to understand the increased aggregating capacity of the hydrolysates. The resulting fat replacer is then incorporated into skim milk to produce fat-free cream cheese. The quality attributes of the cream cheese, such as appearance, texture, and heat-melting behavior, will be tested. To scale up production, an extrusion processing is used. A techno-economic analysis of the process is conducted to calculate the energy consumption and production costs relative to traditional

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technologies. This project aligns with the program's priorities by enhancing sustainability and food quality attributes through advanced processing and bioprocessing technologies.

Animal Health Component

Animal Health Component: 0%

Research Effort Categories

Basic	60%
Applied	40%
Developmental	0%

Classification

Knowledge Area (KA)	Subject of Investigation (SOI)	Field of Science (FOS)	Percent
502	3430	2000	40%
501	1412	2020	60%

Knowledge Area

[502] New and Improved Food Products

[501] New and Improved Food Processing Technologies

Subject Of Investigation

[3430] Cheese

[1412] Peas (dry)

Field Of Science

[2000] Chemistry

[2020] Engineering

Keywords

dairy, plant proteins, protein aggregation, proteolysis, enzymatic reactive extrusion, fat-replacer

Goals / Objectives

Our long-term goal is to efficiently produce aggregates of hydrolyzed plant proteins using industry-relevant processes for quality improvement of fat-free dairy products with less energy consumption. To achieve so, three specific goals are proposed. Goal 1: Optimize the condition to produce plant protein hydrolysates with maximized aggregating capacity. By changing the hydrolysis time and enzyme to substrate ratio, the degree of hydrolysis of plant protein varies. This further determines the surface chemistry and molecular weight of the hydrolysates, resulting in a distinct response towards heat. By controlling the degree of hydrolysis, protein hydrolysates with maximized aggregating capacity will be achieved under low to mild heating conditions. Goal 2: Identify the quality characteristics of fat-free cream cheese containing PPH aggregates. Aggregates of protein hydrolysates will be expected to deform and

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disassemble under shear force due to their high molecular flexibility. They could also interact with caseins to weaken or disrupt the intactness and continuity of casein-networks. Both contribute to a softer texture and smoother mouthful feelings of fat-free cream cheese. Goal 3: Determine the extrusion condition to large-scale production of PPH aggregates and its techno-economic analysis. The strong shear force provided within extruder will facilitate enzyme diffusion among protein matrix capable of conducting hydrolysis at high protein concentration. With controllable temperature in the extruder, PPH will be aggregated while the enzyme is inactivated. By adjusting the extrusion parameter and enzyme proportion, a process with more energy, time and cost efficiency will be achieved.

Project Methods

Aim 1: Optimize the condition to produce PPH aggregates under mild heat. Lab-extracted pea protein isolate will be suspended in water, mixed with protease, and hydrolyzed for a short duration at various enzyme to protein ratio. The produced hydrolysates with the highest aggregating capacity will be identified as the optimized condition based on the response surface methodology. The degree of hydrolysis, molecular weight, surface hydrophobicity, surface charge and available -SH group of the hydrolysates will be measured by TNBS method, SDS-PAGE, fluorescence spectroscopy, zeta sizer, and Ellman's reagent, respectively. The hydrolysates will be heated to form aggregates followed by examination of Morphology, size and molecular flexibility of the aggregates will be examined by SEM, Mastersizer, and relaxation solidstate NMR, respectively. Molecular forces that are involved in the aggregation of hydrolysates will be measured by using different solvents. Aim 2: Identify the quality characteristics of fat-free cream cheese with PPH aggregates. Skim milk containing plant protein hydrolysates or its aggregates will be used to form cream cheese. The proximate of cream cheese will be measured according to AOAC standards. The cheese microstructure will be characterized by using confocal microscopy SEM. Amplitude, frequency and temperature sweep will be conducted to measure the viscoelasticity and melt heating behavior. Firmness, spreadability and adhesiveness will be measured by using a textural analyzer with. Sensory analysis will also be conducted by quantitative descriptive analysis-QDA™, using a randomized (full) block design. Judges (eight to ten) will be pre-screened and trained to determine the aroma, flavor, texture & mouthfeel attributes of the cream cheese samples. Aim 3: Determine the eREX condition for large-scale production of PPH aggregates and its techno-economic analysis (TEA). Commercial plant protein isolate will be mixed with water containing protease. They will be extruded under various moisture content, screw speed and feeding rate to identify the optimal condition with the highest cheese softening capacity. A system-level process simulation and economic analysis assuming the extrusion process are being scaled up to a commercial scale of 2,000 tons/yr. Material and energy balance, and flow rate will be quantified based on SuperPro Designer simulation of heat and mass balances. Quantified information will be used to calculate total chemical, energy, and enzyme consumption and thus variable operating costs. Fixed operating cost, including labor and various overhead items, will be quantified. The capital investment, total net profit, internal rate of return, and net present value as well as sensitivity analysis will also be calculated.