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1. Dutta, D., & Sit, N. (2024). Casein-based films reinforced with bamboo shoot fibers modified by ultrasound and cellulase. *Industrial crops and products*. *222*, 120112.
2. Dutta, D., & Sit, N. (2024). A Comprehensive Review on Types and Properties of Biopolymers as Sustainable Bio-based Alternatives for Packaging. *Food Biomacromolecules* (Accepted).
3. Dutta, D., & Sit, N. (2024). Preparation and characterization of potato starch-based composite films reinforced by modified banana fibers and its application in packaging of grapes. *International Journal of Biological Macromolecules*, *254*, 127791.
4. Dutta, D., & Sit, N. (2024). Comprehensive review on developments in starch-based films along with active ingredients for sustainable food packaging. *Sustainable Chemistry and Pharmacy*, *39*, 101534.
5. Dutta, D., & Sit, N. (2023). Comparison of properties of films prepared from casein modified by ultrasound and autoclave treatment. *Journal of Food Measurement and Characterization*, *17*(5), 5426-5439.
6. Dutta, D., & Sit, N. (2022). Comparison of Properties of Films Prepared from Potato Starch Modified by Annealing and Heat–Moisture Treatment. *Starch-Stärke*, *74*(11-12), 2200110.
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Participation in International/National Conference

- D. Dutta & N. Sit, (2024). “Development and Characterization of Potato Starch and Bamboo-Shoot Fiber-Reinforced Biodegradable Film” at International

Carbohydrate conference 2024, CARBO-XXXVIII organized by Gauhati University, Assam, India.

- D. Dutta and N. Sit, (2022), Properties of film developed from various properties of heat-moisture and ultrasound-treated starch-protein blends", Oral Presentation at Virtual International Conference SAFETy-2022 organized by the Department of Food Engineering & Technology, Tezpur University, India, and Department of Soils, Water & Agricultural Engineering, Sultan Qaboos University, Oman.
- D. Dutta and N. Sit, (2021), Effect of native and hydrothermally-modified potato starches on properties of developed films", Oral Presentation at Virtual International Conference SAFETy-2021 organized by the Department of Food Engineering & Technology, Tezpur University, India, and Department of Food Science and Technology, University of Georgia, USA.

List of Awards

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REVIEW ARTICLE

Application of natural extracts as active ingredient in biopolymer based packaging systems

Ditimoni Dutta[1] · **Nandan Sit**[1]

Revised: 31 March 2022 / Accepted: 15 April 2022

Abstract Active packaging systems come under novel techniques and are creating demands in food packaging aspects. They are specially designed for food products where shelf life is a key driving factor. Their wide range of functionality preserves the color, texture, smell, and taste of the food item retaining their freshness and edibility for longer than any other methods available on market. An active ingredient in packaging systems enables efficient consumable quality which resulted in reduced complaints from consumers. However, techniques must be inexpensive and environment-friendly. The use of biodegradable packaging systems reinforced by exploiting natural compounds forms the latest trend to attract consumer demand in substituting synthetic preservatives in foods that can protect against food spoilage. Natural extracts have gained commercial importance in active packaging nowadays for the delivery of safe and high-quality foods that are being employed in both fresh and processed produce. Development and use of innovative active packaging systems in varied forms are expected to increase in the future for food safety, quality, and stability. The review overviews the beneficial effects of plant acquired components in modulating product quality in packaged form for commercial aspects in the market.

Keywords Active packaging · Natural ingredients · Biodegradable packaging

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Introduction

Packaging of foods comprises advanced technological methods mostly employed for the welfare of societies. Protecting food from harmful effects of oxygen scavengers, water vapor emitters, ultraviolet radiation including contamination from microorganisms and chemical agents forms the main purpose behind food packaging. In the food supply chain, fresh fruit packaging is a vital unit activity beginning from the farm until the product is received by the final consumer. Active food packaging functions by releasing active agents into the food that facilitate improved food quality with stability. This new kind emerged through changing patterns with respect towards customer preferences regarding food products with a longer shelf life (Leistner 2000). The active ingredient within the food packaging system plays an active role in the quality of food and durability either by acting as scavengers or inactivating deleterious compounds through the release of desirable components, having antimicrobial or antioxidant properties. In the preparation of coatings and films, biological materials like proteins, polysaccharides, lipids, or such mixtures are successfully used (Mali et al. 2005; Gottifredi 2007). Even, natural extracts obtained from green plant parts or agricultural wastes forms an ideal candidate by maintaining eco-friendliness and economics. They are also composed of several phenolic compounds and metabolites such as thymol, chitosan, nisin, cinnamon, rosemary, essential oils, clove oils, oregano, thyme, carvacrol, enzymes and many others that can perform as antimicrobial and antioxidant polymers in nature (Priyadarshi and Rhim 2020).

COVID-19 has played a major role in economic development and food systems worldwide having a decisive impact on public health. The packaging industry has faced

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Starch
www.starch-journal.com

Comparison of Properties of Films Prepared from Potato Starch Modified by Annealing and Heat–Moisture Treatment

*Ditimoni Dutta and Nandan Sit**

This study modified potato starches using hydrothermal treatment, i.e., annealing (ANN) and heatmoisture treatment (HMT). ANN in the ratio (1:2) of potato starch and water at 60 °C is performed for a day. For HMT, native starch is exposed to 110 °C maintained at 20% moisture content (M.C.) for 8 h. Potato bio-films (native and modified) are prepared by solution casting method using glycerol as a plasticizer. The properties of native and modified starches along with developed films are evaluated. HMT-modified starches showed lower solubility (10.5%), lower swelling power (21.2 g g^{-1}), lower freeze-thaw stability, and exhibited non-Newtonian fluid behavior. Films produced from HMT starch have decreased solubility (13.57%), WVP (0.20 g mm m^{-2} h^{-1} kPa^{-1}), and enhanced mechanical properties (7.62 MPa tensile strength, elongation of 11.36%, and seal strength 4.06 MPa) compared to annealed and native starch films. ANN starch increased the elongation (9.36%) with lower solubility (17.31%) and WVP (0.65 g mm m^{-2} h^{-1} kPa^{-1}) of the starch films compared to the native starch. Also, the result shows that the potato starch-based films biodegraded within 15 days. The developed biodegradable packaging films could meet various packaging requirements using physically modified potato starch which has better film forming properties and is also eco-friendly.

1. Introduction

The increasing concern of pollution caused by non-biodegradable items forms the principal driving agent for the production of bio-based packaging materials with enhanced qualities for sustainability. The efficient substitution of similar materials with biodegradable polymers derived from degraded sources (i.e., biopolymers) could reduce the severe environmental impact of packaging materials. Starch is considered one of the most promising biopolymers for manufacturing biodegradable films because of its affordability, availability, renewability, and biodegradability. It forms the major component (carbohydrates) of potato tubers, accounting for almost 75% (dry matter).[1–3] Starch granules comprise two α-glucan forms, i.e., amylose and amylopectin, representing 98–99% (dry weight), varying according to their botanical origin. Amylose contains straight polymeric chains with α-1,4-glycosidic linkages that have good film-forming properties similar to fibers,[4] while amylopectin consists of α-1,4-glycosidic and α-1,6-glycosidic linkages at the branching points possessing good thickening and freeze-thaw stability.[5]

Potato starch (PS) is considered the most promising carbohydrate for food packaging applications.[6–8] Its starch granules are relatively large (25–100 μm), occurring in B-type crystalline structures.[9] The potato starch comprises about 80% large macromolecules of amylopectin and 20% high-molecular-weight amylose, along with a higher extent of covalent phosphate bonds.[10] A significant advantage of potato starch over other starch sources is the lower gelatinization temperature, higher paste consistency and gelling ability, transparency of its pastes, increased viscosity, easier expansion, and considerable neutral taste.[11] Although these unique characteristics together make potato starch an excellent choice as a functional biomaterial in the case of food and polymer science,[12,13] potato starch usage containing 80% large macromolecules of branched amylopectin has several limitations for packaging, such as poor mechanical strength, poor moisture sensitivity, greater dissolving temperature, and poor solubility.[14,15] Starch modification is adapted to overcome native starch constraints to fit-in starch to specific industrial food applications.[16,17] Starch is functionally altered by physical, chemical, biotechnological, enzymatic treatments, or their combination.[18]

Hydrothermal modification is the physical modification that involves changes without destroying the starch granule structure forming irreversible modifications in the characteristics of starch.[19] Also, hydrothermal modifications have the advantage that they do not produce hazardous waste and improve starch properties at low cost using simple and environment-friendly processes.[20–22] Annealing (ANN) and heat–moisture treatments (HMT) are the two hydrothermal changes of starches that take place at temperatures beyond the glass transition temperature (T_g) and beneath the gelatinization temperature. Annealing and heat–moisture treatment enable the production of biodegradable films with improved functionalities. The annealing and heat–moisture treatment effects vary on the botanical origin of starch, moisture content, temperature, and duration.[20] ANN is

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ORIGINAL PAPER

Comparison of properties of films prepared from casein modified by ultrasound and autoclave treatment

Ditimoni Dutta[1] · **Nandan Sit**[1]

Received: 9 March 2023 / Accepted: 26 June 2023

Abstract

This study proposes an eco-friendly method to create biodegradable packaging films using physical modification i.e., ultrasound (US) and autoclave (AC) for 15 and 30 min. Five treatments were performed: NC (native casein), AC 15, AC 30, US 15, US 30, and films were prepared by incorporating glycerol. The functional characteristics of native and modified casein, in addition to the properties of developed casein films, were examined. The films developed from native and modified casein were characterized by thickness, solubility, water vapor permeability (WVP), mechanical properties, sealability, and thermal stability. As per the results, US 30 modified casein showed higher protein solubility (76.43%), emulsion stability (52.42%), emulsification activity (57.84%), water holding capacity (120.51%), oil holding capacity (108.43%) and lower bulk density (0.62 g cc^{-1}) and particle density (1.324 g cc^{-1}) values. The films produced from US 30 treated casein had reduced solubility (14.95%), WVP (0.357 g mm m^{-2} h^{-1} kPa^{-1}), with increased mechanical characteristics (9.37 MPa tensile strength, 9.87% elongation, and seal strength of 4.23 MPa) in contrast to autoclave treatment and native casein films. Thermo-gravimetric analysis outputs of the film samples showed stronger thermal stability upon modification. Further, AC 30 casein films offered increased elongation (8.89%) with lower WVP (0.384 g mm m^{-2} h^{-1} kPa^{-1}) and lower solubility (17.65%). Thus, the positive impacts of ultrasonic modification duration upon functional and physicochemical characteristics of casein along with developed films could be a good option for packaging of fresh-cut and ready-to-eat products.

Keywords Casein modification · Functional properties · Biodegradable films · Barrier properties · Mechanical properties

Abbreviations

AC	Autoclave
US	Ultrasound
DW	Distilled water
M.C	Moisture content
NC	Native casein
OHC	Oil holding capacity
WHC	Water holding capacity
EA	Emulsifying activity
ES	Emulsifying stability
WVP	Water vapor permeability
TS	Tensile strength

Introduction

Food packaging materials have become increasingly important with a focus on improving the shelf life of packaged foods [1]. Biodegradable films provide benefits such as flexibility, renewable resources, and cost efficiency, making them valuable in sustainable food packaging with the aim of developing packaging that is both safe and environmentally conscious [2]. Food products can be packaged using biodegradable films by protecting them from moisture, oxygen, fats, and flavors [3]. Polysaccharides, proteins, and lipids, or a combination of the three, are used to create such films [2, 3]. Protein solutions are known to form good films because proteins can develop macromolecular networks in three dimensions that are enhanced and sustained by hydrogen bonds, and hydrophobic linkages including disulfide bonds, they are one of the most promising sources of raw materials for the development of biodegradable films [1]. Proteins are often strengthened by adding casein during food processing [3]. Casein protein contains 80% of milk protein including α, β, and κ-casein components [4]. In aqueous solutions,

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Preparation and characterization of potato starch-based composite films reinforced by modified banana fibers and its application in packaging of grapes

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ARTICLE INFO

Keywords:
Bio-composites
Biodegradability
Mechanical
Thermal
Water vapor permeability

ABSTRACT

The current study focuses on the preparation and characterization of potato starch-based biocomposite films by reinforcing them with banana fiber. The banana fibers were modified using ultrasonication and cellulase enzyme, individually and in combination. Both native and modified banana fibers underwent physical, morphological, FTIR, and crystallinity analyses. The resulting biocomposite films, created by incorporating native and treated banana fibers, were then evaluated for their mechanical, thermal, barrier, and biodegradable properties. The findings indicated that combining ultrasound with enzyme treatment of banana fibers in the potato starch matrix led to a substantial reduction in water-sorption and water-vapor permeability (0.156 g mm m^{-2} h^{-1} kPa^{-1}) of the packaging films. Additionally, the mechanical properties (5.02 MPa-Tensile strength, 4.27 MPa-Sealability) of the films significantly improved with the inclusion of modified banana fibers. FTIR analysis revealed similar spectra for all modified samples, along with enhanced crystallinity. Moreover, the thermal stability of the developed films was enhanced by the incorporation of modified banana fibers. Scanning electron microscopy showed that the modified fibers exhibited smooth surfaces and an even distribution of spaces compared with the native fibers. The biocomposite films demonstrated biodegradation within 42 days. Furthermore, the packaging application was tested with grapes, which showed that the films could maintain storability for up to 8 days. Overall, these results suggest a promising eco-friendly method for producing packaging films with biocompatible, biodegradable, and non-toxic properties.

1. Introduction

Global concern about waste has sparked interest in renewable resources, leading to the development of sustainable research environments to protect the ecosystem. The World Environmental Day celebrated on June 5, 2023, focused on the campaign #BeatPlasticPollution, which aims to raise awareness about environmental issues and drive transformative changes in global environmental policies. The production of completely biodegradable polymers presents an excellent alternative to synthetic polymers because of the abundance of renewable natural resources [1]. Starch has emerged as one of the most promising renewable resources for manufacturing biodegradable plastics. Despite their potential, starch-based films possess inherent drawbacks, such as brittleness, moisture sensitivity, and difficulties in processability, which restrict their application in the packaging field [2]. In response to this, numerous experiments have been conducted to enhance the quality of processed starch films by co-blending them with other substances that offer high mechanical strength and superior processability [3]. Natural fibers can serve as a favorable substitute for synthetic fibers when reinforced with polymer composite materials [4]. To obtain high-performance starch-based composite materials, reinforcing agents such as jute, banana, flax, and corn can be added to the starch matrix [5]. Banana fiber, derived from the pseudo-stem of the banana plant, exhibits remarkable qualities such as high strength, minimal elongation, strong moisture absorption capacity, great potential, and biodegradability, making it a promising candidate for

Abbreviations: a_w, water activity; CFU, Colony forming unit; DI, De-ionized water; DW, Distilled water; EMC, Equilibrium moisture content; ET, Enzyme treatment; ET + US, Enzyme treatment combined with ultrasound; M.C, Moisture content; OHC, Oil holding capacity; PS, Potato starch; rpm, revolution per minute; US, Ultrasound; US+ET, Ultrasound combined with enzyme treatment; WHC, Water holding capacity; WVP, Water vapor permeability.

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Comprehensive review on developments in starch-based films along with active ingredients for sustainable food packaging

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ARTICLE INFO

Keywords:
Active ingredients
Antimicrobial agents, antioxidant
Biodegradable food packaging
Starch-based nanocomposites

ABSTRACT

Starch-based films have gained significant attention in the food packaging industry due to their potential to address environmental concerns and provide sustainable packaging solutions. This comprehensive review consolidates recent advancements in starch-based films utilized for sustainable food packaging, emphasizing the integration of active ingredients. Active ingredients play a crucial role in enhancing the functionality and performance of starch-based films. The review begins by depicting the structural composition of starch and its processing techniques, highlighting the factors influencing film properties such as mechanical strength, barrier performance, and biodegradability. It elucidates the methods employed to enhance the functional attributes of starch-based films, including blending with various biopolymers, starch-based nanocomposites, and to achieve superior film characteristics. Furthermore, the review explores the incorporation of active ingredients into starch-based matrices, encompassing antimicrobial agents, antioxidants, and oxygen scavengers. It scrutinizes the methodologies used for incorporating these components into films, assessing their efficacy in extending shelf life, preserving food quality, and ensuring safety. Finally, the review critically evaluates the challenges and limitations encountered in the development of starch-based films, addressing issues related to moisture sensitivity, mechanical properties, and scalability. Lastly, the review outlines future research directions, emphasizing the need for multifaceted approaches involving innovative processing techniques, nanotechnology applications, and sustainable sourcing of raw materials to further enhance the efficacy and applicability of starch-based films in sustainable food packaging.

Abbreviations

AA	Ascorbic acid
CA	Cassava starch
DSC	Differential scanning calorimetry
EO	Essential oil
PBAT	polybutylene adipate co-terephthalate
PCL	Polycaprolactone
PHA	Polyhydroxyalkanoates
PLA	Polylactic acid

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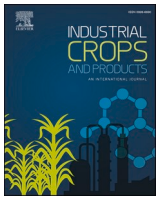

Casein-based films reinforced with bamboo shoot fibers modified by ultrasound and cellulase

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ARTICLE INFO

Keywords:
Barrier properties
Biodegradability
Modification
Natural fibers
Sustainable packaging

ABSTRACT

Bamboo-shoot fiber (BSF)-reinforced casein-based films were developed using ultrasonication (US) and cellulase treatments (ET), both individually and in combination as a sustainable alternative to plastic packaging. These treatments aimed to enhance the compatibility and interfacial adhesion between BSF and casein. Native and modified BSF were characterized for physical, morphological, and FTIR (Fourier transform infrared-spectroscopy) including X-RD (X-ray diffraction). The resulting bio-composite films, created through a solution casting technique, were analyzed for their barrier, thermal, mechanical, along with biodegradable characteristics. The mechanical properties, such as tensile strength (7.81 MPa) and elongation at break (3.26 %), along with barrier properties (water-vapor permeability: 0.025 mm/m^2/h/kPa; film solubility: 13.65 %), showed significant improvements for ultrasound combined with cellulase treatment compared with films made from untreated fibers. Enhanced sealing strength (8.06 MPa) and sealing efficiency (118.63 %) were also achieved, meeting essential packaging material requirements. Fourier transform infrared spectroscopy (FTIR) analyses and X-ray diffraction (XRD) results indicated that ultrasound combined with cellulase-treated BSF had lower film solubility (15.24 %), water holding capacity (145.91 %), and oil holding capacity (122.67 %), with higher crystallinity. The modified films exhibited uniform thickness, and the combined fiber treatments with cellulase and ultrasound resulted in a more compact matrix and a lighter appearance. Treatment also removed most non-cellulosic content, revealing a cellulose-I structure and improved thermal stability. The developed film degraded within three weeks, thus confirming its environmental friendliness. Further, the developed film preserved Heiyai upto 9 days showing its ability for shelf-life extension. These findings suggest that BSF-reinforced casein films are viable, sustainable packaging solutions.

1. Introduction

In the present era, researchers are focused on developing innovative materials with unique characteristics to fulfill the growing and varied needs of both industry and society (Norrrahim et al., 2021). India possesses 30 % of the world's bamboo resources, with a total growing area of 14.94 million hectares, producing 53,336 million culms, equivalent to 402 million tons. In the North-east region, bamboo covers 5.35 million hectares, yielding 24,330 million culms, or 179 million tons (Jeemoni et al., 2021). The abundant and renewable nature of bamboo resources could contribute to the efficient and cost-effective production of biofilms on a large scale. As the demand for eco-friendly packaging solutions continues to rise, exploring the potential of bamboo shoot fiber (BSF) in film packaging presents an exciting opportunity for the industry. In northeast India, tribal communities widely ferment bamboo shoots due to their numerous health benefits, high medicinal value, and significant nutritional value. (Behera and Balaji, 2022). Bamboo shoots are rich in cellulose fibers, which can be extracted and used to create biodegradable films (Nie, 2023). With a high cellulose content of around 40–50 %, BSF has garnered consideration as a possible sustainable alternative for packaging materials given its abundance, renewability, and biodegradability (El Foujji et al., 2021). Research has shown that BSF possess

Abbreviations: BSF, bamboo shoot fiber; DI, deionized water; DW, distilled water; EAB, elongation at break; ET, enzyme-treatment; ET + US, enzyme-treatment combined with ultrasound; FRP, fiber-reinforced polymers; M.C., moisture-content; OHC, oil-holding capacity; PVOH, polyvinyl alcohol; RPM, revolution per minute; TS, tensile strength; US, ultrasound-treatment; US + ET, ultrasound combined with enzyme treatment; WHC, water-holding capacity; WVP, water-vapor permeability.

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REVIEW ARTICLE

FOOD BIOMACROMOLECULES

WILEY

A comprehensive review on types and properties of biopolymers as sustainable bio-based alternatives for packaging

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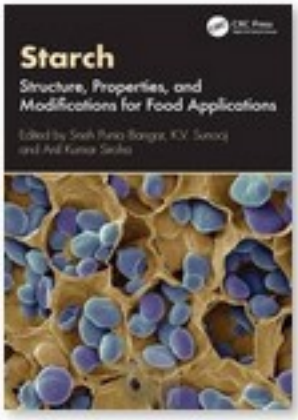
Abstract

Biopolymers, derived from renewable resources such as plants, animals, and microorganisms, are emerging as sustainable alternatives to traditional petroleum-based polymers. The review examines the key characteristics of biopolymers, including their biodegradability, biocompatibility, and potential for carbon neutrality. These characteristics are crucial for determining their suitability for different packaging applications and their potential to reduce environmental pollution. While acknowledging the promise of biopolymers, the review also addresses challenges such as production costs, scalability issues, and performance limitations. Strategies to enhance biopolymer performance, including plasticization, blending, and nanomaterial reinforcement, are discussed. Interestingly, the review highlights the emerging field of active and intelligent packaging systems, which incorporate antimicrobial agents and sensors to extend shelf life and monitor food quality in real-time. The review emphasizes the importance of life cycle assessments in evaluating the overall environmental impact of biopolymer-based packaging compared to conventional alternatives. In conclusion, this review provides an overview of the current state of biopolymer research and identifies areas for future investigation. By synthesizing current knowledge, identifying challenges, and highlighting opportunities, this review contributes to ongoing efforts to create a more sustainable and circular packaging industry.

KEYWORDS

bio-based plastics, bio-nanocomposites, biodegradability, natural polymers, sustainable materials



Chapter

Ultrasound Treatment

By Ditimoni Dutta, Nandan Sit

Book Starch

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ABSTRACT

Ultrasound modification has emerged as an advanced method for altering starch physico-chemical, functional, morphological, and thermal characteristics. This chapter provides a comprehensive overview of the effects of ultrasound on starch, including its processes and applications. Ultrasound technology generates mechanical vibrations that induce physical and chemical changes in starch, influencing its structural and functional properties. The mechanisms involved, such as cavitation, mechanical shear, and temperature changes, are thoroughly discussed. Ultrasound treatment leads to changes in the granular structure of starch, affecting its crystallinity, morphology, and gelatinization capabilities. It also enhances starch solubility and digestibility, which is beneficial for improving the texture and digestibility of starchy foods in the food sector. The chapter highlights the various applications of ultrasound-treated starch in different prospects, such as its use as an emulsifier, thickener, and stabilizer in processed foods and as a packaging film. Challenges related to industrial scalability and cost-effectiveness are also acknowledged. The chapter concludes with a look ahead at potential research avenues and the possibility of combining ultrasound with other advanced technologies for further starch modification opportunities. In conclusion, ultrasound treatment holds promise for enhancing starch-based products across diverse industries, warranting continued investigation and development to unlock its full potential for sustainable and improved applications.

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at International Carbohydrate Conference on "Recent Advances in Glycoscience and Glycotechnology" organized by Department of Bioengineering and Technology, Gauhati University and the Association of Carbohydrate Chemists and Technologists India (ACCTI), held from 4-6 December 2024.

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INDIAN PHYTOPATHOLOGICAL SOCIETY
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"Women scientists in plant health management for sustainable development goals"

A National Conference of the Women, by the Women, for the Women Scientists

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This Certificate is presented to the authors

.....Dilimoni Dutta & Nandan Sit.....

for securing 1st/2nd/3rd Position in Oral/Poster presentation on the topic

..Crafting Sustainable Fruit ... bamboo fibres.....

*in the national conference on "**Women scientists in plant health management for sustainable development goals**" organized by Assam Agricultural University, Jorhat and Indian Phytopathological Society, New Delhi during*

22- 23, December, 2023 at Assam Agriculture University, Jorhat-13, Assam

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Title : PROPERTIES OF FILMS DEVELOPED FROM VARIOUS PROPORTIONS OF HEAT-MOISTURE AND ULTRASOUND TREATED STARCH-PROTEIN BLENDS

Authors : DITIMONI DUTTA AND NANDAN SIT

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Certificate

This is to certify that Dr./Mr./Ms. DITIMONI DUTTA has participated as Oral Presenter at SAFETy-2021, organized by the Department of Food Engineering & Technology, Tezpur University, Assam, India, and Department of Food Science & Technology, University of Georgia, Georgia (US) in Association with AFST(I) Tezpur Chapter during 24th-25th June, 2021.

Title: Effect of native and hydrothermally modified potato starches on properties of developed starch films

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