DEVELOPMENT AND APPLICATION OF MULTICOMPONENT EDIBLE FILMS

by

Yi Wu

A DISSERTATION

Presented to the Faculty of

The Graduate College at the University of Nebraska

In Partial Fulfillment of Requirements

For the Degree of Doctor of Philosophy

Major: Interdepartmental Area of Nutrition

Under the Supervision of Professor Marilynn Schnepf

Lincoln, Nebraska

December, 1999

UMI Number: 9952697

UMI®

UMI Microform 9952697

Bell & Howell Information and Learning Company
300 North Zeeb Road
P.O. Box 1346
Ann Arbor, MI 48106-1346

DISSERTATION TITLE

Development and Application of Multicomponent Edible Films

BY

Yi Wu

SUPERVISORY COMMITTEE:

APPROVED	DATE
Marilyn Schnepf Signature	12/3/99
Marilynn Schnepf Typed Name	
Susan Cuppett Signature	12/3/99
Susan Cuppett Typed Name	
Curtis Weller Signature	12/3/99
Curtis Weller Typed Name	
Nancy M Betts Signature	12/3/99
Nancy Betts Typed Name	
Fayrene L Hamouz Signature	12/3/99
Fayrene Hamouz Typed Name	
Signature	
Typed Name	

GRADUATE COLLEGE
UNIVERSITY OF NEBRASKA

DEVELOPMENT AND APPLICATION OF MULTICOMPONENT EDIBLE FILMS

Yi Wu, Ph.D.

University of Nebraska, 1999

Lay Abstract

Advisor: Marilynn Schnepf

Edible films and coatings based on carbohydrates, proteins and/or lipids were developed and tested for their effectiveness on controlling moisture loss and rancidity of precooked ground beef patties. Factors affecting instrumental analysis of rancidity in precooked meat, such as sample preparation method and sample amount were examined. The results were used in the follow-up edible film application studies. Wheat gluten (wheat protein), soy protein, carrageenan (a type of carbohydrate from edible seaweeds) and chitosan (a type of carbohydrate from shells of shellfish) films and coatings had different effects on maintaining the quality of precooked patties after 3-day refrigerated storage. All coatings were as effective as polyvinyl chloride film (a type of plastic film) in reducing patty moisture loss and more effective than films. Wheat gluten, carrageenan or soy protein coatings and carrageenan films were effective in inhibiting rancidity in patties with wheat gluten coating being the most effective. Incorporating fatty acids, especially 30-40% of palmitic acid and stearic acid, had a significant impact on moisture barrier properties and mechanical properties of soy protein films. Films were composed of soy protein and propyleneglycol alginate (PGA, a type of carbohydrate) showed improved moisture barrier properties and mechanical properties by adding PGA up to 10% and 17.5 %, respectively. The tortuous network

structure found in films containing starch, alginate (a type of carbohydrate from brown algae) and fatty acids may have contributed to the improved moisture barrier properties of these films, especially films with 30% fatty acids. Both soy protein-fatty acid films and starch-alginate-fatty acid films were heat sealable. During 6-day refrigerated storage, starch-alginate-stearic acid based films were effective in limiting moisture loss from precooked patties. Starch-alginate films and starch-alginate-stearic acid, that included food antioxidants, tocopherols, were effective in inhibiting rancidity in patties. All edible films, except for tocopherol-coated films, were generally not as effective as polyester bags (plastic bags) in controlling moisture loss and the development of rancidity.

DEVELOPMENT AND APPLICATION OF MULTICOMPONENT EDIBLE FILMS

Yi Wu, Ph.D.

University of Nebraska, 1999

Advisor: Marilynn Schnepf

Edible films and coatings based on polysaccharides, proteins and/or lipids were developed and tested for their effectiveness in controlling moisture loss and lipid oxidation of precooked ground beef patties. Factors affecting gas chromatographic analysis of lipid oxidation in precooked meat, such as sample preparation methods, equilibration times and sample phase fraction, were examined. They were controlled and used in the follow-up edible film application studies. Wheat gluten, soy protein, carrageenan and chitosan films and coatings had different effects on maintaining the quality of precooked patties after 3-day storage at 4°C. All coatings were as effective ($P < 0.05$) as polyvinyl chloride film in reducing patty moisture loss and more effective than films. Coating with wheat gluten, carrageenan or soy protein and wrapping with carrageenan films were effective ($P < 0.05$) in lowering patty thiobarbituric acid reactive substance values (TBARS) and hexanal values with wheat gluten coating being the most effective ($P < 0.05$), which resulted in about 28% and 48% reduction in TBARS and hexanal, respectively. Incorporating fatty acids, especially 30-40% of palmitic acid and/or stearic acid, had a significant ($P < 0.05$) impact on water barrier properties and mechanical properties of soy protein films. Composite films of soy protein and propyleneglycol alginate showed improved ($P < 0.05$) moisture barrier properties and

mechanical properties by adding propyleneglycol alginate up to 10% and 17.5 %, respectively. The tortuous network structure observed in starch-alginate-fatty acid films using scanning electron microscopy may have contributed to the improved moisture barrier properties of these films, especially in films with 30% fatty acids. During 6-day storage at 4°C, starch-alginate-stearic acid based films were effective ($P < 0.05$) in limiting moisture loss from precooked patties. Tocopherol treated starch-alginate films and starch-alginate-stearic acid films were effective ($P < 0.05$) in inhibiting the lipid oxidation in patties by lowering TBARS and other oxidation products. All edible films, except for tocopherol-coated films, were generally not as effective ($P > 0.05$) as polyester vacuum bags in controlling moisture loss and lipid oxidation, and their effects were storage time dependable.

Dedicated to

my daughter, Natalie, for her love

and wish her "qing chu yu lan er sheng yu lan (green arises from blue but is superior to blue)"

and to my husband, parents, sister and brother for their love

ACKNOWLEDGMENTS

This is a very exciting moment as another journey in my life is coming to an end. No words can really help me to express my deep and sincere appreciation and gratitude to the many people who supported and assisted me in accomplishing this journey that was full of challenges.

I would like to express my sincere appreciation to my advisor, Dr. Marilynn Schnepf, for her valuable guidance and support during my graduate program. Her faith in my abilities and her consistent encouragements allowed me to rise to many challenges and to achieve many seemingly impossible goals for my professional career and life. The many moments she shared her insights with me about the meaning of research, education and life will always inspire me and stay with me.

I am also greatly indebted to Dr. Fayrene Hamouz, Dr. Curtis Weller, Dr. Susan Cuppett and Dr. Nancy Betts for serving as members of my supervisory committee. Their support, advice and encouragements have provided me with the freedom to discover and study my dissertation project. Their influence on my professional development and my life, and the friendship developed through the years shall never be forgotten.

Sincere gratitude is extended to Dr. John-Wang Rhim, a visiting professor in Dr. Weller's laboratory, for his support, suggestions and assistance during my dissertation studies. It has truly been a pleasure to work with him.

Special thanks go out to Dr. Aristippos Gennadios for his teaching in determination of water vapor permeability of edible films, and his advice and encouragements for my career development.

The assistance I received from Dr. Kent Eskridge and Dr. Anne Parkhurst in the

Department of Biometry is gratefully acknowledged. The assistance provided by Tom Bargar in the Department of Veterinary and Biomedical Science in performing scanning electron microscopic examination and the development of photomicrographs, and by Dayna Dughman in the Industrial Agricultural Products Center in conducting tensile strength and elongation testing on edible films are also highly appreciated. The completion of this dissertation would not be possible without these people's valuable suggestions and contributions.

Sincere appreciation goes to David Giraud for his technical assistance in the analysis of tocopherols and especially, for his kindness, encouragements and friendship. Without his valuable help, my family and I would not be able to solve many daily life puzzles and English puzzles that we have encountered during the years in Nebraska.

A huge thanks is extended to all members of the Department of Nutritional Science and Dietetics. Special thanks also goes to Dr. Tim Carr, Dr. Julie Albrecht, Dr. Beverly Benes, Dr. Judy Driskell, Dr. Wanda Koszewski, Donna Hahn, Julie Block, Jeannie Pittam, Lori Rausch, Cindy Stuefer-Powell, Cindy Hayes, Ahmad Sulaeman and Carol Ray. I have enjoyed the many moments of talking and working with you and thanks for all of the little things that made a big difference.

A very special thank you is expressed to Dr. Jerry Maranville in the Department of Agronomy for his role in bringing me to this new world and to Nebraska for my study. The mid-night warm welcome given by Dr. Jerry Maranville and Mrs. Donna Maranville at the Lincoln Municipal Airport when I first arrived in this country and the time I spent with them are always remembered with gratitude.

Sincere thanks also go out to Dr. Stanley Jensen in the Department of Plant Pathology for providing me the opportunity to work with him and for his friendship.

I would like to extend my appreciation to all my friends here and in China for their consistent encouragements and forever friendship.

I wish to express my heartfelt appreciation to my parents for inspiring me with willingness and courage to learn, for all kinds of supports they have given me throughout my entire life and for giving me the confidence to strive for only the best in life. And to my sister and brother, for their love and consistent supports.

Finally, I wish to express my deepest love and heartfelt appreciation to my baby daughter, Natalie, and my husband, Shengming, for their love, sacrifices, patience, understanding and encouragements during the course of my graduate journey. When challenges were greatest, they were always behind me. Without their loving support along the way, I could not have completed this journey!

And dear Natalie, your Dr. Mom can spend more time with you along your growing up journey now.

Yi

PREFACE

Research in the development and application of edible films and coatings has recently intensified. This growing interest in the concept of edible films and coatings is driven by the increased consumer demand for high quality, long shelf-life and ready-to-eat foods, environmental consciousness for disposal of nonrenewable food packaging materials, and the opportunities for creating new market outlets for both traditional and novel agricultural crops which are the sources of the desired film-forming ingredients. One of the most useful functions of edible films and coatings is their ability to act as barriers, either to gas, solute or moisture. Besides their barrier properties, edible films and coatings can function as carriers for food additives such as antioxidants, antimicrobial agents and nutrients.

Edible films and coatings have been developed from polysaccharide, protein and lipid materials. Such films along, in combination or with other components have exhibited the promise for innovative uses as food protective materials in different type of foods. However, the application of edible films and coatings including multicomponent edible films on processed foods, especially those characterized by a high moisture content such as precooked meat products, is an area that has received little attention.

The objective of this dissertation was to 1) determine the effectiveness of several edible films and coatings on moisture loss and lipid oxidation from precooked ground beef patties, 2) develop soy protein-based and starch-alginate-based multicomponent edible films, and 3) determine the effectiveness of starch-alginate-based multicomponent edible films as barriers and/or antioxidant carriers on moisture loss and lipid oxidation from precooked ground beef patties.

This dissertation consists of eight different chapters.

The first chapter is an overview on the research of the development and application of multicomponent edible films.

Each of the next six chapters is written as an individual research article complete with introduction, materials and methods, results and discussion, and references. The first research article reports a methodology study on static headspace gas chromatographic analysis of lipid oxidation of precooked meat products. The method developed was used in studies described in the second and sixth research articles. The second research article demonstrates how coatings and films developed from wheat gluten, soy protein, carrageenan and chitosan could be used as moisture and/or oxygen barriers to maintain quality of precooked ground beef patties. To improve moisture barrier properties, multicomponent films were prepared and characterized using soy protein-fatty acids and soy protein-propyleneglycol alginate as discussed in the third and fourth research article, respectively. The fifth research article presents observations on moisture barrier properties and microstuctures of multicomponent films of starch-alginate-fatty acids. The last article describes the effectiveness of the previously developed starch-alginate-stearic acid film as a moisture and oxygen barrier and as an antioxidant carrier on maintaining quality of precooked ground beef patties.

A summary of all dissertation studies and recommendations for future research are given at the end of this dissertation.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

DEVELOPMENT AND APPLICATION OF MULTICOMPONENT EDIBLE FILMS AND COATINGS: A REVIEW

This review is to be submitted to:

Advances in Food and Nutrition Research.