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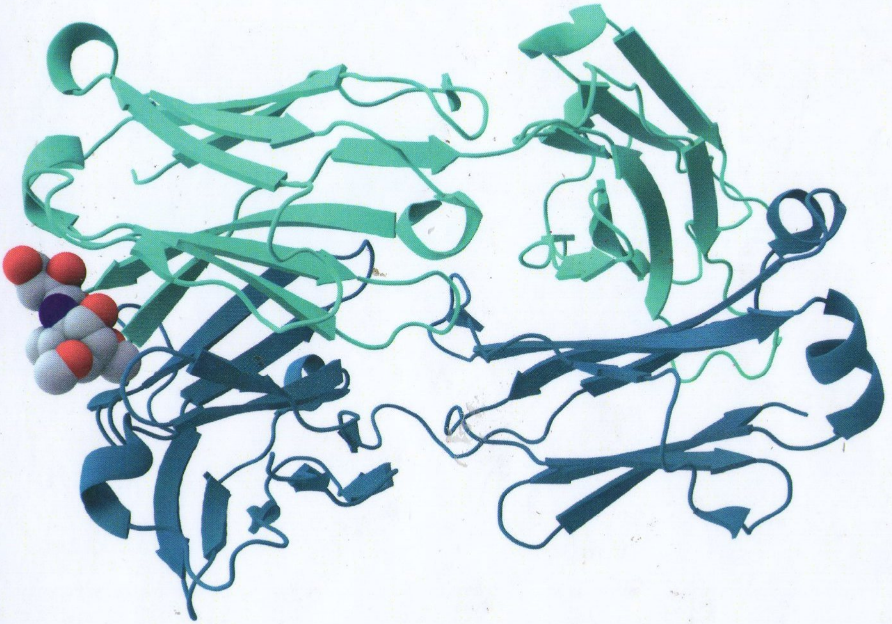

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BIOPOLYMERS INTERACTIONS
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WHEAT BIOPOLYMERS INTERACTIONS IN THE BREADMAKING

Monography

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This book reviews current knowledge of the structure and properties of the storage proteins and other biopolymers of wheat, flour and bread. The role of the gluten forming proteins and complex biopolymer matrixes in wheat flour, several structure-function relationships based on the molecular level and determination the quality of the dough and bread also discussed. Intermolecular structures between the main biopolymers (proteins, starch, lipids) of wheat flour with functional ingredients (dietary fibers, inulin, phenolics, glucans) during bread making are also highlighted and dicussed.

This text will be valuable as useful reference for scientists, engineers and technologist from industry, university, laboratories involved in cereal and bread research, and for undergraduate, graduate and postgraduate students of faculties of food science, food engineering, biochemistry and biotechnology of bread making.

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PREFACE

In our edition of "State of the art in bread production", published in 2012, we focused on the delivery of bread making information in a concise manner. Being lecturers of biochemistry, food biotechnology and bread making, we had been searching for a book that covered theoretical aspects of biotechnology of bread making, involving chemical interactions of various food components in the employed ingredients, including formation molecular structures – complex biopolymer matrixes, between the main biopolymers (protein, starch, lipids) of wheat flour during bread processing. These interactions can be adjusted to create desirable baking products once the underlying biochemical, chemical, physical and technological processes are well understood.

Wheat products are staple foods in most parts of the world. In particular, the unique viscolastic properties of hydrated gluten proteins make wheat flour-water system (dough) a highly interesting object of research. A common purpose of many investigations is the prediction of dough processability and finished products quality. Therefore an in-depth understanding of both the characteristics as well as the chemical and physical changes during the formation (mixing) and processing (fermentation, molding, thermal end treatment) of wheat dough is necessary.

Many of these changes, which take place on the molecular level, not only become visible in the resulting dough structure but also influence dough handling, processability, and product quality. The gluten protein structure, which is alleged to determine the mechanical behavior of the dough, plays a primary role in all of these steps.

Flour-water systems are a biological complex medium wherein the structure-function relationship represents a predominant position. For a target orientated product design it is essential to know the quantitative structure-function relationship of the bread matrix interactions. This is valid for material as well as for food and cereal engineering. Further, knowledge of the structure-function relationship plays a particular role in the prediction and specific modification of

processing capabilities. This knowledge of the dependency between the structural properties of a component and its derived functional characteristics enables to establish theories and models that move away from qualitative, descriptive science towards a fundamental proposition.

A wide range of flour and dough analyses are commonly used to quantify and forecast structural changes on different scales in wheat dough, with a special focus on the wheat proteins which are the basis for the development of relationships.

In recent years, remarkable progress has been made in the elucidation of cereal protein structures and their behaviors during bread making. Gluten proteins are of particular interest since their unique viscoelastic characteristics predominate the mechanical behavior of wheat dough.

The microstructure is the connective link between the molecular level and the mechanical behavior of dough's macrostructure. Since the microstructure can be analyzed in a noninvasive matter, this could be a direct link to developing an enhanced structure-function relationship. So far, much work has been done in investigating dough and dough protein microstructure in particular; however, a quantitative characterization of wheat dough's structural features has yet to be achieved.

Flour provides the structure in baked goods. Wheat flour contains proteins that interact with each other when mixed with water, forming gluten – elastic framework which stretches to contain the expanding leavening gases during rising. The protein content in the flour affects on the dough stretching.

Wheat gluten proteins are considerable interest to their functionality in bread. They form extensive insoluble protein networks in dough, which are stabilized by intermolecular disulfide bonds.

Gluten proteins play a key role in determining the unique baking quality of wheat by conferring water absorption capacity, cohesivity, viscosity and elasticity on dough. Gluten proteins can be divided into two main fractions according to their solubility in aqueous alcohols: the soluble gliadins (monomeric proteins with alpha/beta-, gamma- and omega-type subunits) and the insoluble glutenins (divided into the high-molecular-weight HMW and low-molecular-weight LMW subunits). Both fractions consist of numerous, partially closely related protein components characterized by high glutamine and proline contents.

Non-covalent bonds such as hydrogen bonds, ionic bonds and hydrophobic bonds are important for the aggregation of gliadins and glutenins and implicate structure and physical properties of dough.

HMW proteins are divided into three domains, a central repetitive domain flanked by short, non-repetitive N- and C- terminal domains. The terminal domains are suggested to have a globular structure with high contents of alpha-helix. They have several cysteine residues present, whose function in dough may lie in the formation of intermolecular disulfide bonds leading to cross-linked network.

The large central repetitive domain consists of β-turns, and was proposed to form a "super-secondary structure" of an elongated, so-called β-spiral and may contribute to gluten elasticity. This model describes as semi-flexible cylinder.

The precise molecular basis for the elastic properties o gluten and dough is not known, but is thought to involve contributions from the structures of the individual subunits and their interactions via non-covalent and covalent bonds.

A thorough knowledge of the size and shape of these types of structures would considerably help to understand HMW proteins and their dominant role in gluten dough textures.

This book presents an account of current development in structural network of the gluten and others biopolymers of the wheat flour. The structure and functionality of baked products are all about macromolecular interactions in which all major classes of macromolecules (protein, starch, arabinoxylans, lipids) play an important role.

In recent years, the general population of the industrialized world has demonstrated an increased interest in the role of foods with an addition of physiologically active plant ingredients (i.e. phytochemicals) in well-being and life prolongation, as well as the prevention of initiation, promotion and development of

cancer, cardiovascular diseases, osteoporosis and obesity. Those foods are defined as functional. Consumer awareness of the importance of functional foods has greatly grown in the past years.

Interests in incorporating bioactive ingredients such as dietary fiber and polyphenolic substances into popular foods like bread have grown rapidly due to the increased consumer health awareness. Bakers are seeking natural ingredients to replace chemically produced ones.

Functional foods with elevated level of antioxidants and dietary fibers are of high demand because of their associated health benefits, including maintenance health and protection from diseases, such as cancer, cardiovascular and degenerative diseases. As bread is a common component in western diet, including Ukraine, it may be a convenient food to deliver dietary fibers, phenolic antioxidants of high concentrations.

In this book we review the published literature on experimental studies of bread making to identify the scopes of further investigation into functional bread, with particular reference to the incorporation of dietary fibers, phenolic ingredients and associated technical challenges. We consider the chemical composition of the ingredients used in bread making, with a specific focus on the impact of added substances on dough functionality and bread quality. We also discuss the interactions among wheat proteins, polysaccharides (pectin, inulin, beta-glucan, starch) and phenolic antioxidants during dough development and baking process, and supposed the mechanisms associated with the changes in the structure and conformation of wheat proteins in the level of supramolecular structures.

Herbs and some plants are a rich source of dietary fiber (pectin substances, inulin, hemicelluloses et. all.), polyphenols and others bioactive substances, in view of the antioxidant property, would play an important role in the prevention of some diseases. The review provides a comprehensive overview about the incorporation of potential functional ingredients obtained from herbs and plants to wheat bread.

Thus, preparation of baked products with different phytoextracts may prove a valuable means of enhancing polyphenol consumption and improve the antioxidant status in Ukrainian consumers.

The purpose of this part of book is to investigate the properties of breads enhanced with phenolic antioxidants and pectin fibers. Results suggest that the functional ingredients (polyphenolics and polysaccharide substances) used in bread formulation can induce various changes in secondary structure of wheat proteins. Adding phytoextracts causes changes in conformations and polymer structure of wheat gluten and wheat starch.

Wheat proteins and starch during dough development and bread baking caused differences in cross-linked macrostructures. The treated breads gained β-sheets in the protein's secondary conformation at the expense β-turns.

Protein structure of gluten of breads can be modified considerably by adding dietary fibers (pectin) and polyphenols. Schematic "Loop and Train" models for breads enhanced with phenolic antioxidants and dietary fiber (pectin, β-glucan, inulin) illustrate the possible conformational changes in the structure dough complex biopolymer matrixes due to the presence of added functional ingredients.

This book is intended for scientists, engineers and technologist from industry, university, laboratories involved in cereal and bread research, and for undergraduate, graduate and postgraduate students of faculties of food science, food engineering, biochemistry and biotechnology of bread making.

It is hoped that the information which this book contains will help to understand structures and properties of the basic macromolecules and components of wheat flour and breads, their each other interactions and explain complexity of the formation of finished products and the regulation high consumer properties.

We would like to express our thanks to Professors, Doctors of the technical sciences Fedir Pertsevoy and Volodimir Kovbasa for their time and efforts in reviewing this book.

From the team of authors,

professors L.Kaprelyants and K. Iorgachova

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INTRODUCTION

Wheat is one of the most important food crops, witch flour produced from starchy endosperm. More wheat is produced annually than any other cereal crop and it is probably the world`s foremost food plant. The following [1] database the quantities of wheat produced in 2016 are (in thousand metric tons): EU – 160,1; China – 130,1; Russia – 60,0; USA – 55,8; India – 86,5; Ukraine – 27,2; Canada – 27,6. While the EU is at the top spot, Ukraine takes the seventh spot, followed by Canada.

Wheat is used primarily as a food in bread products, pasta, noodles, pastry, breakfast cereals, baby foods and animal feed. Wheat is the grain most commonly used to make flours. Certain varieties may be referred to as "clean" or "white". About 75 % of all harvested wheat is made into flour.

It is therefore, very important to understand the biopolymer composition of wheat flour and evaluate the effect of refined milling. It is necessary to find a way to improve the quality of the refined flour products.

Wheat flour is almost unique amongst cereal flours in processing characteristics that enable it to be used for preparing an extensive range of baked products. The principal characteristic that governs its wide usage is its viscoelasticity when hydrated. The component in the wheat flour with the property of viscoelasticity is the gluten [1, 2].

Knowledge of the gluten structure is essential for understanding the way gluten proteins interact with each other and with other flour biopolymers (starch, lipids, non-starch polysaccharide and others) and constituents. Differences in gluten functionality result from differences in composition, structure or distribution of gluten and other polymers [3, 4].

A great deal of work has been concluded on how to explain the structural network of the gluten. Among the cereal flours only wheat flour can form three-dimensional viscous-elastic dough when mixing with water.

It is generally agreed that the bread making potential of wheat flour is related to the glutenin proteins. As result, research on the glutenin proteins has been intense [4, 5].

The technological significance of gliadin and glutenin in bread making has been attributed to their contribution to dough extensibility and elasticity, respectively [5, 8].

By combining several techniques have proved the structure of polymeric gel in a large range of length scale form and evidenced that proteins self-assemble in a hierarchical fashion. This system appears therefore as a unique model system to investigate the supramolecular organization of gluten proteins and its impact on the viscoelastic properties of gluten gels [9].

The critical question, and one that continues to generate much research, is "What happens on the molecular level during dough mixing?" The research is complicated by the complexity of the dough system and the fact that the main species involved (glutenin) is a high molecular weight polymeric protein that is to a large extent, insoluble. Nevertheless, progress towards the answer is being made [10].

The aim of the work presented in in this book was to review the interactions and correlation between gluten forming proteins and other biopolymers of wheat flour. Different authors relate these proteins to the baking properties of flour and the quality of the baked products [7, 8].

Common approaches to the problem are presented on the diagram below:

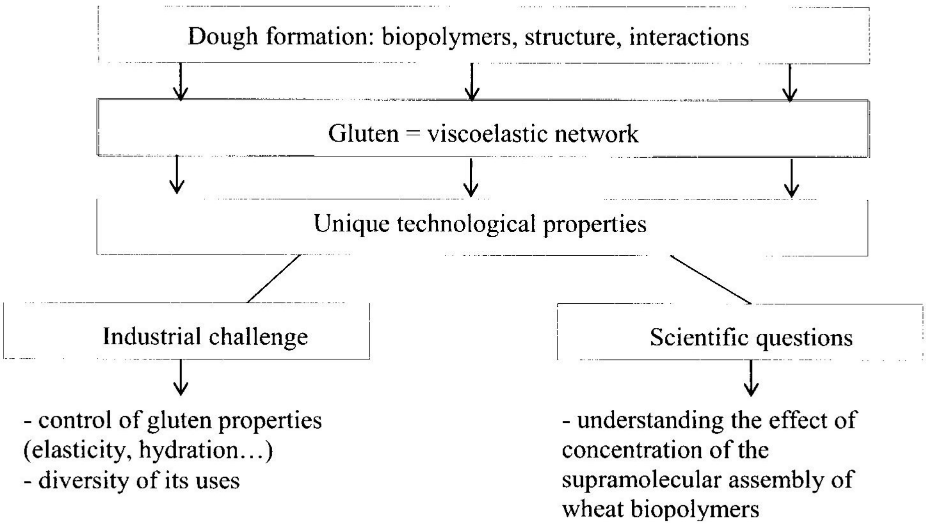

Figure 1 General approaches to the study of unique technological properties wheat biopolymers

Numerous studies have been devoted to various aspects of bread making – a process in which wheat flour, water, salt, sugar and yeast are mixed in varying proportions into viscoelastic dough subjected to fermentation and baking. Bread is a leavened food produced via fermentation of wheat flour sugars derived from starch polysaccharides involving chemical interactions of various food components in the employed ingredients. These interactions can be adjusted to create desirable products once the underlying chemical and physical processes are well understood

We review the published literature on experimental studies of bread making to identify the scope of further investigation into functional bread, with particular reference to the incorporation of biological active ingredients and associated technical challenges.