POLYMERS for PACKAGING APPLICATIONS

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POLYMERS FOR PACKAGING APPLICATIONS

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Sajid Alavi, PhD, is a Professor of Extrusion Processing and Food Engineering in the Department of Grain Science and Industry at Kansas State University, Manhattan, Kansas, USA. He received his BS degree (1995) in Agricultural Engineering from Indian Institute of Technology (Kharagpur), MS (1997) in Agricultural and Biological Engineering from the Pennsylvania State University, and PhD (2002) in Food Science/ Food Engineering from Cornell University, Ithaca, New York. Dr. Alavi's research activities are focused in the areas of food engineering, extrusion processing for industrial and food applications, nanocomposites for packaging applications, mathematical modeling of flow and structure formation in biopolymer melts during extrusion, food microstructure imaging, structure-texture relationships, and new approaches to global food security and nutrition through processing. He has secured over $6.3 million in extramural funding from various federal, state, and industrial sponsors for his research program. He has supervised seven PhD and 13 Masters level students. Dr. Alavi's received the coveted 2010 Young Research Scientist Award from AACC International, formerly the American Association of Cereal Chemists, which is an important recognition for research accomplishments.

Dr. Alavi designs technology and R&D solutions for numerous food, feed and pet food processors, and is involved in processing and food aid related projects in USA, Africa, India, and other countries around the world. He has been invited to speak at numerous international forums and institutions in USA, Italy, South Africa, Brazil, India, Mozambique, and China. He has provided training and networking opportunities to 800 industry leaders from 30 countries spanning all six continents through his internationally reputed short course "Extrusion Processing: Technology and Commercialization" and similar offerings and workshops in other countries such as India, Brazil and Mozambique.

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LIST OF ABBREVIATIONS

AAGR	8Average annual growth rate
ADC	Analog to digital convertor
AFM	Atomic force microscope
ATR	Attenuated total reflectance
BC	Bacterial cellulose
BSEs	Back-scattered electrons
CAP	Controlled-atmosphere packaging
CAS	Controlled atmosphere storage
CSIR	Council for Scientific and Industrial Research
CSLM	Confocal scanning laser microscope
DMTA	Dynamic mechanical thermal analysis
DRS	Dielectric relaxation spectroscopy
DSC	Differential scanning calorimeter
DTA	Differential thermal analysis
EELS	Electron energy loss spectroscopy
EM	Elastic modulus
EMI	Electromagnetic interference
EPA	Environmental protection agency
ERH	Equilibrium relative humidity
FDA	Food and drug administration
FDM	Finite difference method
FEA	Finite element analysis
FIB	Focused ion beam
FID	Flame ionization detector
FSI	Food spoilage indicator
FSL	Food-simulating liquids
FTIR	Fourier transforms infra-red spectroscopy
GC-MS	Gas chromatography-mass spectrometry
GFSE	Grape fruit seed extracts
GPC	Gel permeation chromatography
HDPE	High density polyethylene
HIPS	High impact polystyrene
HPLC	High-performance liquid chromatography
ICI	Imperial chemical industry
ICP-MS	Inductively coupled plasma-mass spectrometry
ICPs	Intrinsically conductive polymers
IFT	Institute of Food Technologists
ILT	Ideal laminate theory
LCA	Life cycle assessment

LDH	Layered double hydroxide
LEO	Lemongrass essential oil
LLE	Liquid–liquid extraction
LMIS	liquid metal ion source
LWA	Liquid water absorption
MAP	Modified atmosphere packaging
MWNT	Multi-walled nanotubes
NCF	Nanocellulose fibers
NIAS	Non-intentionally added substances
NMR	Nuclear magnetic resonance
NNI	National nanotech initiative
OML	Overall migration limit
OMLS	Organically modified layered silicate
OP	Oxygen permeability
OTR	Oxygen transmission rate
PCNC	Polymer–clay nanocomposites
PNCs	Polymer nanocomposites
RFID	Radio frequency identification
RH	Relative humidity
SEM	Scanning electron microscope
SML	Specific migration limit
SPI	Soy protein isolate
SPM	Scanning probe microscope
STM	Scanning tunneling microscope
SWNT	Single-wall nanotube
TEM	Transmission electron microscope
TEMAP	Thermally equilibrious modified atmosphere packaging
TEMT	Transmission electron microtomography
TPS	Thermoplastic starch
TS	Tensile strength
UPC	Universal Product Code
VARTM	Vacuum assisted resin transfer molding
VRH	Variable range hopping
WAXS	Wide-angle X-ray scattering
WPI	Whey protein isolate
WVP	Water vapor permeability
WVTR	Water vapor transmission rate
XRD	X-ray diffraction

PREFACE

The world-wide market for plastic films and sheets used in various packaging and non-packaging applications exceeds $100 billion and is growing at an annual rate higher than the global gross domestic product. The polymeric materials that are used include low and high density polyethylene, polyethylene terephthalate, biaxially oriented polypropylene, copolymer polypropylene, poly(vinyl chloride) and ethylene vinyl alcohol. No doubt this massive usage of plastics is driven by several benefits including convenience and economics, but the drawbacks are also becoming apparent.

Plastics do not biodegrade, primarily because they are made of synthetic polymers and no microbe has yet evolved that can feed on them. Disposal of the millions of tons of plastic waste generated every year takes up huge areas in the form of landfills. Plastic polymers may not be toxic themselves but the myriad of chemical monomers added to them for improving their properties can be released to the surroundings and contact materials over time or under conditions such as heat and exposure to sunlight or photodegradation. An example is bisphenol A or BPA that is added as a plasticizer but banned for use in applications involving packaging or containers for infant food due to its potential toxic effects. Waste plastics can also attract and accumulate chemical poisons present in the environment such as water contaminated with DDT and PCB. A striking example of the problem with plastic waste is the 'The Great Pacific Garbage Patch' covering an area roughly the twice the size of France in the Pacific Ocean*. The combined weight of plastic accumulated in this 10-meter deep plastic soup is estimated at three million tons and increasing steadily due to several major sea currents converging to this region that bring flotsam from the Pacific coasts of Southeast Asia, North America, Canada and Mexico. Its toxic effect on marine life is just beginning to be understood.

In this backdrop, the development and use of bio-based and/ or biodegradable polymers is gaining importance. Polylactic acid, polyvinyl alcohol and polybutylene succinate are plastic materials that can be decomposed by bacteria or other living organisms. These materials often lack the performance characteristics, such as strength, flame retardance or barrier properties, of conventional plastics but they can be enhanced by using various nanofillers. Research on such nanocomposites is also gaining widespread attention.

Developments in the above mentioned areas were focus of the International Conference on Polymers for Packaging Applications (ICPPA 2012) organized at Mahatma Gandhi University in Kottayam, India from March 31st to April 2nd, 2012. Scientists from the U.S.A., U.K., France, China, Thailand, Malaysia, Iran and India presented cutting edge research in the areas of food, non-food, and industrial packaging applications of polymers, blends, nanostructured materials, macro, micro and nanocomposites, and renewable and biodegradable materials. This book and its focus have origins in the aforementioned international conference. Several of the speakers at ICPPA 2012

contributed to the various chapters. Due to reasons related to sustainability, recycling and regulatory issues, the topics discussed in the conference and ongoing research has gained even greater urgency in the last two years.

This book emphasizes interdisciplinary research on processing, morphology, structure, and properties as well as applications of polymers in packaging of food and industrial products. It is useful for chemists, materials scientists and food technologists. It details physical, mechanical, electrical and barrier properties of polymers and biopolymers, as well as sustainability, recycling, and regulatory issues. The book contains a good mix of review chapters and experimental studies, and is divided into four major sections. Chapters in the first section provide an overview of traditional plastics in packaging applications including a specific example related to food packaging. Additives used for improving properties of plastics are described along with experimental studies on their migration. The second section focuses on biopolymers and biodegradable plastics, and their synthesis, commercial production, properties and use in packaging of food and industrial products and biomedical applications. Recycling and life cycle analysis for plastics and bioplastics is also discussed. The next section contains chapters related to nanotechnology and bio-nanocomposites in packaging applications. Various nanofillers, including phyllosilicates, metallic nanofillers, carbon nanotubes and graphene, are described and also regulatory issues discussed. Analytical techniques and approaches based on mathematical modeling are presented for understanding the structure, and barrier and mechanical properties of bio-nanocomposites. The final section has chapters describing the state-of-the-art in modified atmosphere packaging for foods, and innovations related to active and intelligent packaging. The last chapter presents an intriguing concept of conductive polymers for functions such as electromagnetic shielding and active packaging.

The editors have made a conscious effort to select authors from various parts of the world representing diverse disciplines including material science, physics, packaging engineering, microbial sciences and food technology. We would like to thank them profusely for their high quality submissions and contributing to this truly multi-disciplinary effort. Special thanks to our readers, and the editorial staff of Apple Academy, Inc. for their assistance and helpful suggestions at every step.

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