DRYING '91

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PREFACE

This volume consists of papers selected from those presented at the 7th International Drying Symposium, held in Prague in August 1990 in conjunction with the CHISA'90 Congress. This Symposium set records in terms of the number of attendees (over 300) as well as the number of papers presented (over 250). The selected papers have been edited and revised, where necessary, to bring them up-to-date. Hence, we believe, the title of this volume, "DRYING '91", to be an appropriate one. We are grateful to the authors for their patience and the additional time and effort they devoted to revising their papers to meet the requirements of this book.

With over 1000 papers presented at International Drying Symposia since their inception in 1978, the DRYING series provides an excellent source of information on current drying R & D around the world. It is also easy to recognize from this series of books the growing interest, both in industry and academia, in the unit operation of drying. This interest is triggered by one or more of the following factors: escalating energy costs, higher quality requirements, new products and processes, increased production rates, as well as the renewed awareness of the negative environmental impact of emissions caused by combustion of fossil fuels most commonly used to supply the energy for drying.

We would like to express our sincere appreciation to all the contributors to this volume, members of the International Advisory Panel of the IDS series, and members of the local organizing committee for the 7th Symposium. Numerous individuals and professional organizations - too numerous to list - helped in several ways with the organization and thus this resulting volume. Also we want to thank Dr. B. Čermák, Dr. S. Grabowski, Amit Mujumdar and Purnima Mujumdar for their assistance in compiling this book. We are pleased that Elsevier Science Publishers have agreed to take over the publication of this series and we hope that the series will continue to provide an effective vehicle for international, multi-disciplinary and inter-industry transfer of drying know-how.

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Drying 91, edited by A.S. Mujumdar and I. Filková

HEAT AND MASS TRANSFER IN POLYMER AND GEL DRYING

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ABSTRACT

A vast class of products which can be described as polymer-solvent systems necessitates to be dried for final presentation to the customer. These systems are usually non-porous and owing to the elasticity of the polymeric structure this state can prevail until later stages of drying.

The mass transport inside the product is greatly affected by the deformation. In order to take into account the convective flux associated to the shrinkage, the commonly accepted method is to write the mass equation in a polymer related frame of reference.

The influence of stress over mass transport is still an open theoretical question. Physical evidence of casing and collapse indicates that not only stress field affects mass transport but also provokes damage in the structure.

The rheology of the polymer-solvent system can alter the constitutive equation for diffusion and again introduce more complexity in the description of the phenomenon.

Although the mass flux of evaporation is constant for the initial wet stages of drying, the drying rate itself generally varies because of the change in volume and in surface. Variable diffusivity accounts for the shape of the drying curves.

INTRODUCTION

The drying of polymers and gels relates to many fields of technology and to many substances : agro-industry (cellulose, paper, wood), food industry (meat, starch), chemical industry (fibers, paints, membranes, ceramics) and even civil engineering where clay material is widely used.

Macromolecules and water form a complex structure with a special evolution with moisture content. The concept of bound and free water is vastly insufficient to describe and understand the physico-chemical nature of the interaction of solvent and solid. Even if one restricts the question to non-porous structures, omitting capillary potentials associated to interfaces with gas, one has to take into account the influence over mass transport of water domains imprisoned in macromolecular structures and the role of water in the glassy-rubbery transition.

The understanding of phenomena occurring in drying is necessary for the designing of the process but it is even more necessary to control the quality of the final product. The moisture content field brings deformation of the body and, in turn, develops stress in the structure. This stress is responsible for the damage and the final appearance of the product. The effort in research on these phenomena is not in line with their economical importance mainly because of the multidisciplinary aspects.

The essential of the work undertaken by food or chemical engineers has been to apply intermediate models to describe and predict the drying kinetics : these models are too crude for quality control. Mechanical and civil engineers have developed ideas from irreversible thermodynamics or continuum mechanics generally ending with a complex set of equations for mechanical equilibrium, heat and mass transport.

This paper intends to discriminate between what is definitely established and what is still under discussion for non-porous water macromolecular systems.

NATURE AND CONSTITUTION

Polymers of technical interest constitute a large class of materials (TABLE 1) and many of them are associated with a solvent either in the polymerisation stage or in the elaboration stage.

NATURE	DESTINATION	EXAMPLES
Artificial and synthetic polymers	plastics	polystyrène
	elastomers	isoprène
	fibers	polyacrylonitrile
Biological macromolecules	structural proteins	keratine - collagene
	nucleic acids	ADN
	polysaccharide	amylose - cellulose

TABLE 1 : SUBCLASSES OF POLYMERS

The quantity of water and/or solvent to be eliminated by drying from polymers depends on the nature of the polymer and on the process. When water comes from the polymerisation stage itself, one ends up with a relatively small amount of solvent but when water is introduced after polymerisation to obtain a gel or a colloïd suspension for product elaboration, the quantity of water can be enormous (several kg per kg of matter d.b.).

The quantity of bound water associated to polymers varies according to the chemical structure of the macromolecule. Usually alcohols and carboxylic groups retain more water than amides and amines which in turn are more hygroscopic than olefins or aliphatic chains. FIGURE 1 and 2 show various isotherms.

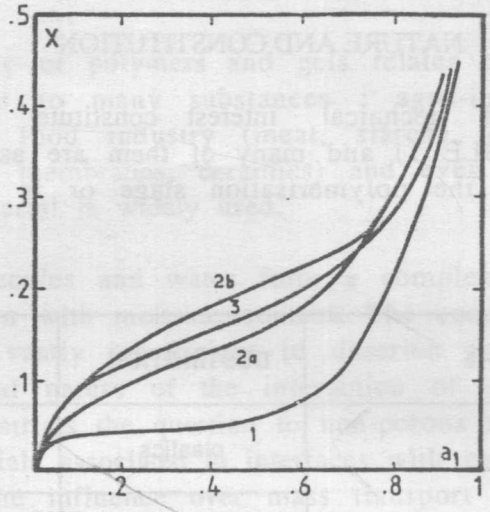

FIGURE 1 : WATER SORPTION CURVES FOR GELS TAKEN FROM [1]

1 alginate 25°C
2a sorption water-P.A.
2b desorption water-P.A., 25°C, [1]
3 gelatine

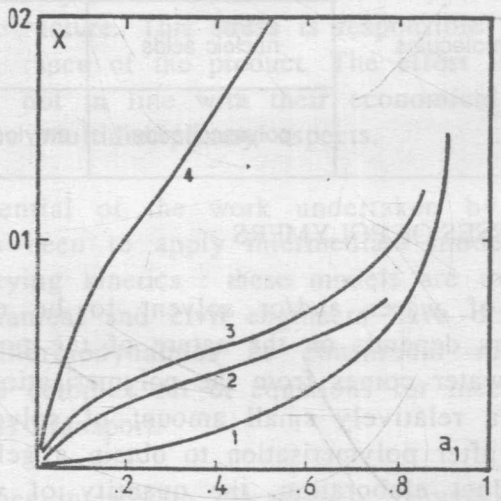

FIGURE 2 : WATER SORPTION CURVES FOR POLYMERS.

1 Natural Rubber, 25°C, [5]
2 P.V.C., 30°C, [4]
3 Monocrystalline cellulose, 25°C, [2]
4 Carboxymethyl-cellulose, 25°C, [3]