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Published by

The American Association of Cereal Chemists
St. Paul, Minnesota

Library of Congress Catalog Card Number: 81-71369
International Standard Book Number: 0-913250-22-8

Printed in the United States of America

The American Association of Cereal Chemists, Inc.
3340 Pilot Knob Road
St. Paul, Minnesota 55121

CEREALS: A RENEWABLE RESOURCE

Theory and Practice

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INTRODUCTION

This book contains edited proceedings of the International Symposium on Cereals: A Renewable Resource, Theory and Practice that was held in Copenhagen, Denmark in August 1981 under the sponsorship of the American Association of Cereal Chemists and the Danish Cereal Society in association with the Carlsberg Research Center.

Scientists from ten countries presented and reviewed, along with participants from 21 countries, the extent to which cereals can become a viable renewable resource. The first series of presentations addressed cereal production and utilization. After a review of cereals as a source of tomorrow's chemicals, the potential use of straw and optimization of grain drying are discussed. Various mechanical-technological approaches to fractionate cereals and physical and chemical properties of the fractionated products (as they relate to potential utilization) are detailed. The extent to which chemical, pyrolytic, and biological modifications of cereals can enhance their utilization is reviewed critically. Several papers are devoted to the use of specific grains (sorghum, barley, wheat, triticale, and rice) as sources of food, feed, fuel, and chemicals. These reviews are followed by corresponding ones on conversion and utilization of cereal by-products. The final series of reviews and discussions concerns the technology, economics, and general feasibility of utilizing cereals as fuel sources.

The following are some introductory comments made during the symposium by the program co-chairmen and co-editors of these proceedings. They reflect their thinking on what the symposium was all about, its objectives, and the extent to which the objectives were attained.

Cereals are one of the most important elements in the history of mankind. Cereals made it possible for man to store food and gave him time to meditate how this world functions and how it can be improved. Cereals are thus crucial to the real beginning of our civilization and culture. Lately, many changes have taken place in crop production. A handfull of barley harvested in 1850 and a handfull of barley harvested today look alike. The procedures by which these barleys were produced, however, vary substantially. Many find it difficult to appreciate that while the barleys look alike, there are two different worlds behind them. With the rising fuel prices we have to determine how we can optimize and utilize our renewable resources. That has

obviously to do with technology; what is technology? It relates to the efficiency of the production chain. It also addresses the question how physics, chemistry and biology and the human element can be combined to the benefit of man. Two different types of people can contribute to meeting that objective. At one extreme is the empiricist who aims at practical results and is willing to forego explaining everything in a scientific manner and arranging it all in a perfectly logical way. On the other extreme is the theoritician with his concepts of how nature should be and his desire to persuade nature to be that way. We have catered to none, but tried to bring out the best in both.

We have brought to this symposium three groups of contributors. The first group includes biologists, plant breeders, and farmers, who search for new techniques to produce more, better, and uniquely tailored crops. The co-chairman of the first session said on another occasion "If nothing is produced, nothing can be improved". We must first produce grain so that it can be improved. The second group includes the chemist, biochemist, microbiologist, engineer, and food technologist, who study methods and processes to convert raw materials, by-products and waste materials into various products: foods, feeds, chemicals, and fuel alternatives. In the third interaction group is the economist and the system expert who analyze the feasibility of exploiting, systematizing and optimizing the conversion of renewable resources into needed products. We asked the contributors not to speak in generalities and not to address the same problem. We asked them to address specifics in such a manner that their contributions can be integrated into a unified picture and that there will emerge a perspective of the complex issues with due consideration to technological, environmental, and social impacts.

The main reason for organizing this and related symposia is that in the last millennum we have lived on our capitalized account of fossil sunshine and have severely depleted our resources. We must learn to live on the annual income of energy from the sun, the photosynthetic process. Just as there are many ways to skin a cat there are many ways to tap the energy of the sun. The question is how can we do it best? We hope that proceedings of this symposium can provide exciting, viable, and practical answers. Some of the questions we hope to answer include: Are cereals a renewable resource? If the answer is positive, at what cost and benefit in terms of national economics, available water and soil resources, etc.? Are cereals the best available renewable resource? Or maybe the best way is not to consider cereals a general renewable resource and to concentrate on

cereals as staple foods and look into other plant materials (including some exotic ones) as sources of basic raw materials. Or, maybe, instead of trying to make cereals a source of basic materials, we should use the available research resources to better use cereals as foods. While we grow maize in many places all over the world, only few have a modern technology to utilize the grain as a food. Maize is still used widely as a feed; in part, because we have not yet learned how to convert best maize into acceptable foods. Similarly, barley is a short-time crop and fits well into multi-cropping systems. But few want to eat barley!

Thus, first, we should make clear, a renewable resource for what? -- for food, feed, chemicals, fuels, or any other purpose? The problems can be dealt with in several ways: by attacking general problems of interest to most, or by addressing problems and situations in specific countries with examples that pertain to these countries -- underdeveloped, developing, or developed. Both the questions and the solutions vary widely and depend whether we try the general or the specific approach. We can address general concepts for many countries or can address specifically the whole spectrum, from new concepts to practical implementations including extension in a specific country under specific conditions. We attempted to provide a combination of several approaches.

It is our hope that we have attained some of the objectives. We believe we had the right mix of scientists and technologists from academia, government, and trade and industry from many countries with various perspectives, approaches, and needs (and often divergent views). We hope that their contributions make the proceedings a valuable source of information (food for thought) for agronomists, food scientists and technologists, economists, administrators, and decision makers interested in the potential of cereals as a renewable resource.

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CEREAL PRODUCTION

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ABSTRACT

World cereal production has increased steadily during the last two decades and has more than kept up with population growth. Cereals alone would provide the necessary energy and protein for the whole human population, if they were not included in feed formulations. There exist, however, considerable distribution problems which steadily increase the gap between countries with surplus and those with deficit. About one third of the total increase in production is due to expanding acreage at the cost of other crops and two thirds due to improved cultivars and management. Millet, oat and rye acreages have decreased.

The progress trend seems to be universal and is by no means lower in countries with already high yields. No flattening of the progress curves, presumed to be sigmoid for biological reasons can be traced even at national averages of 5,000-6,000 kg grain/hectare. Record yields from individual fields as well as theoretical calculations of maximal crop productivity indicate 2 to 4 times higher potentials. Under less ideal circumstances, considerable restraints are, however, likely to occur. The energy cost of bacterial symbiosis for nitrogen fixation and of disease resistance, as well as the reduction in weight (total yield) when protein and/or fat are to be produced were selected to illustrate some less frequently considered restrictions.

Since the onset of agriculture, cereals have been by far the most important staple food of the world. They have today alone the potential to support the world human population with needed amounts of calories (Table I).

In the developing countries of Asia and Africa, over two-thirds of the calorie intake is based on cereals. In developed countries of West Europe and North America, a

TABLE I
World Human Population in Relation to Its Cereal Production

REQUIREMENT PER CAPITA:	
Energy (2,500 kcal/day)	900,000 kcal/year
Protein (70 g/day)	25 kg/year
REQUIREMENT OF HUMAN WORLD POPULATION (4,300,000,000):	
Energy	3,870,000,000,000,000 kcal/year
Protein	108,000,000 ton/year
(Cereals contain approx. 3,000 kcal and 100 g protein/kg)	
Energy in weight of cereals	1,290,000,000 ton/year
Protein in weight of cereals	1,080,000,000 ton/year
World production of cereals	1.500,000,000 ton/year
Other harvest products suitable for food	1,800,000,000 ton/year

substantial quantity of cereals goes indirectly into food via feed to animals.

Cereals are also able to produce the required quantity of protein (Table I) although perhaps as yet not of the very best quality. Substantial improvements are, however, within reach by recent success to breed high-lysine types of all cereals with some reservation for the genetically more buffered, polyploid wheats (Axtell 1981). The intake necessary for man to gain equilibrium will be considerably decreased with valuable saving as a consequence. The same holds true when cereals are used as feed. As an illustration, Bressani and Elias (1978) found that children can maintain protein equilibrium on high-lysine maize (opaque-2) by a daily intake of 180 g against 500 g needed of common maize. The corresponding figures for adults were found to be 250 versus 547 g maize/day.

WORLD CEREAL PRODUCTION

The importance of cereals in providing food must be recognized whenever other uses are considered. FAO specialists have recently estimated the number of hungry people to be 455 million or almost 10% of the steadily growing world population. This situation, however, is caused by socio-economic and political conditions together with skewed resources in productive land versus birth rate rather than by a global shortage of food. As evident from Fig. 1[1], world cereal production has for the last two decades been able to more than keep up with the increasing population. The quantities given in the figure should be compared with a Far East annual consumption of approximately 300 kg grain or a West European or a North American consumption of 1,200-1,500 kg grain.

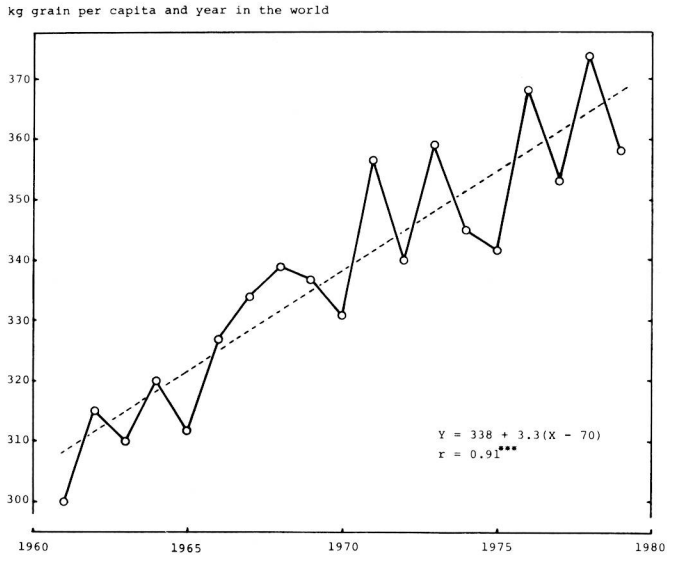

Fig. 1. Average supply of cereal grain in kilogram per world inhabitant over the period 1961-79.

Table II gives the absolute quantities produced in the world. During the last two decades, cereal production has increased by one third. The four leading cereals - wheat, rice, maize and barley - are also the leading crops altogether. In order to understand the existence of hunger in one part of the world and affluence in another, the extremely uneven production capacity needs to be fully appreciated. The surplus and deficit regions have become more and more distinct as, among others,displayed by the changing pattern of world grain grade (Brown 1980; Table III).

WORLD CEREAL ACREAGE

The steadily increasing production is due partly to an expansion of the acreage on which cereals are grown, partly due to an increase yield per unit of arable land. As shown

[1] The statistical compilations in this paper are based on FAO Production Yearbooks since 1945, including USSR since 1959 and all cereals since 1961.

TABLE II
Trend in World Grain Production 1961-79

Cereal crop	Mean of 1975-79 million mtons	Change during last two decades
Cereals, total.....	1,499	+34%
Wheat.....	408	+38%
Rice, paddy.....	366	+31%
Maize.....	352	+39%
Barley.....	176	+43%
Sorghum.....	62	+42%
Oats.....	49	+ 2%
Millet.....	40	+ 5%
Rye.....	33	- 1%
Mixed cereals & others.	12	+27%

in Table IV, an almost insignificant increase of total arable land has occurred in the world during the two last decades. This de facto conclusion should be compared with estimates that 1.8 to 2.8 billion hectares should still be accessible to relatively high-yielding cultivations with present technology, i.e. one to two times more than the 1.4 billion hectares now cropped (Revelle 1976).

What has mainly happened is evidently that the cereals have expanded at the cost of other crops. Their progressive contribution is thus not completely additive, if total production is considered. A restructuring has happened also within the cereal group itself. The stagnant production of rye, oats and millet, as evident from Table II, is to be explained by a considerable decrease in their acreage (Table IV and Fig. 2).

TABLE III
The Changing Pattern of World Grain Trade (Brown 1980)

Region	1934-38	1948-52	1960	1970	1978
	million metric tons:				
North America.....	+ 5	+23	+39	+56	+104
Australia & New Zealand..	+ 3	+ 3	+ 6	+12	+ 14
Latin America.....	+ 9	+ 1	± 0	+ 4	± 0
Western Europe.....	-24	-22	-25	-30	- 21
Africa.....	+ 1	± 0	- 2	- 5	- 12
Eastern Europe & USSR....	+ 5	± 0	± 0	± 0	- 27
Asia.....	+ 2	- 6	-17	-37	- 53

Plus sign indicates net exports; minus sign, net imports.