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Biotechnology-derived nutritious foods for developing countries: Preface

On January 15–17, 2002, a distinguished group of international experts convened to review current scientific information on nutrition needs in developing countries and food-based approaches, including modern biotechnology, that could be used to address these problems. This workshop, "Biotechnology-Derived Nutritious Foods for Developing Countries: Needs, Opportunities, and Barriers," was organized by the International Life Sciences Institute (ILSI) through its Human Nutrition Institute and its International Food Biotechnology Committee, the International Food Policy Research Institute, and the Joint Institute for Food Safety and Applied Nutrition (a multidisciplinary research and education program established in 1996 by the US Food and Drug Administration and the University of Maryland).

Thirty-two individuals with expertise in modern biotechnology, nutrition, or both participated in the discussions. There were representatives from 16 developing countries in Africa, Asia, and Latin America. Other participants included United States–based experts and representatives from industry and academia and representatives from the Food and Agriculture Organization of the United Nations.

The first day of the workshop was devoted to nutrition issues facing developing countries, and to which strategies have worked in the past and why others did not. The second day focused on the potential for modern biotechnology to solve nutrition problems, specific projects that are under way, the barriers these efforts have encountered, and whether the nutrition community is involved in guiding these projects.

The proceedings of this workshop include the expanded abstracts from the plenary sessions as well as a summary developed from small-group discussions, which were then summarized and prioritized by the whole group. The expanded abstracts are those of the authors and do not necessarily represent the views of the sponsoring organizations. The summary was reviewed by all participants.

Funding for the workshop was provided by the ILSI Human Nutrition Institute, the ILSI International Food Biotechnology Committee, and the Joint Institute for Food Safety and Applied Nutrition. For further information about ILSI, please phone ILSI at 202-659-0074, e-mail at ilsi@ilsi.org, or visit the ILSI website at www.ilsi.org.

The organizers are especially grateful to the keynote speakers, Dr. Cutberto Garza and Dr. Gurdev Khush, for providing overviews to set the stage for the small-group discussions. The respondents from developing countries provided invaluable practical experience that was essential to the development of a useful summary. Dr. Barbara Schneeman masterfully handled the difficult task of drawing all of the discussion points together during the final plenary session. Mr. David Schmidt and Ms. Julia Tagwireyi served as the rapporteurs. Each participant contributed to the overall understanding of the issue and helped generate a genuine enthusiasm for the prospects for developing working relationships between the nutrition communities and the agriculture and plant-breeding communities in developing countries. All left the workshop excited about the prospects for improving the nutritional quality and quantity of foods available in developing countries.

Dr. Howarth E. Bouis, International Food Policy Research Institute, Washington, DC

Dr. Suzanne Harris, ILSI Human Nutrition Institute, Washington, DC

Dr. David Lineback, Joint Institute for Food Safety and Applied Nutrition, University of Maryland, College Park, MD, USA

The nutrition situation: An overview

Cutberto Garza

Abstract

Malnutrition remains a major problem in both developing and industrialized countries and is getting worse in selected settings. However, progress has been made in alleviating malnutrition, and the motivation and tools for tackling malnutrition and its consequences have never been more favorable than they are now. Indeed, the genomic developments spawned by the ongoing biological revolution are increasing the pressure to solve problems that lead to low birthweight, stunting, disorders stemming from micronutrient deficiencies, and other manifestations of undernutrition.

Key words: Nutrition, malnutrition, phenotypic engineering

The world's nutrition situation can be characterized most succinctly by the "bad news/good news" cliché. The bad news is that malnutrition remains a major problem in both developing and industrialized countries and appears to be worsening in selected settings. The good news is that progress has been made and that the motivation and tools for tackling malnutrition and its consequences have never been greater and better, respectively. The motivation comes primarily from an ever-increasing understanding of the sustained relevance of nutrition throughout the life cycle and the fundamental roles nutrition plays in developing and sustaining human capital. The enhanced "tool set" is the benefit of unprecedented technological advances and a more functional understanding of the social, economic, and political dynamic that fosters malnutrition.

Focusing on undernutrition, one finds that the incidence of low birthweight in the developing world remains unacceptably high. It ranges widely among regions, from highs of approximately 30% to levels that are as low as those found in industrialized countries. Approximately 17.5 million people are affected in developing countries. Given the long-term consequences of this birth history and increasing survival, the cumulative population that is and will be affected is staggering. The estimated prevalence and number of stunted children is similarly alarming. The approximate prevalence for all developing countries is 29% of all children, or 165 million children. Yet more alarming is the high likelihood that these are underestimates. The urgency that this situation presents is exacerbated when one considers the additional numbers of individuals affected by or at risk for vitamin A, iron, and iodine deficiencies and the likely high numbers of individuals affected by other micronutrient deficiencies that have received less attention, e.g., zinc, folate, vitamin B_{12}, and riboflavin. It also is important to consider that focusing only on classic nutrients is an implicit recognition of our ignorance of other food constituents that account for the health benefits associated with eating patterns that are reflected in current food-based dietary guidelines [1].

The ongoing biological revolution, best illustrated by the unprecedented developments in genomics, steadily increases the pressure to solve problems that lead to low birthweight, stunting, micronutrient deficiencies, and other manifestations of undernutrition. The source of this increasing pressure is our steadily improving understanding of the biological bases of the functional consequences of those conditions. Increased knowledge is uncovering the basis for the intragenerational and, perhaps more disturbing, intergenerational effects of malnutrition, and thus the growing significance of the role of nutrition in "phenotypic engineering." Progressively, the insidious effects of undernutrition on human capital, their high financial and other costs, and the underlying reasons for those costs are becoming clearer.

As is true for poverty, which is the principal root cause of undernutrition, undernutrition is the consequence of an economic, political, and social dynamic

The author is affiliated with Cornell University, Ithaca, New York, USA.

whose interrelationships are salient and whose consequences often also are easily recognizable. As is true of other consequences of this dynamic, undernutrition concomitantly exacerbates, in an adversely synergistic fashion, both the dynamic itself and the undernutrition that is spawned by it. Yet despite this dynamic's overt nature and the salience of its consequences, sustainable interventions for their control are not as obvious as the dynamic itself, its consequences, or explanations for them.

The nutritional status of populations is one of the most easily recognized constituents and outcomes of this dynamic. Its centrality is demonstrated easily by considering the developmental goals adopted by the international community and summarized in the most recent World Development Report 2000/2001 [2]. Seven goals are articulated by that report on behalf of the international community:

» Reduce the proportion of people living in extreme poverty by half between 1990 and 2015.
» Enroll all children in primary school by 2015.
» Make progress toward gender equality and empowering women by eliminating gender disparities in primary and secondary education by 2005.
» Reduce infant and child mortality rates by two-thirds between 1990 and 2015.
» Reduce maternal mortality ratios by three-quarters between 1990 and 2015.
» Provide access for all who need reproductive health services by 2015.
» Implement national strategies for sustainable development by 2005 so as to reverse the loss of environmental resources by 2015.

The biological bases for the assertion that improved nutrition both is a prerequisite for meeting goals such as these and is one of the dividends of achieving them merit exploration. The intra- and intergenerational dimensions of these relationships and the biology that may underpin them will be considered in the context of the present and projected nutrition situation, population pressures, food access, nutrient gaps, and demographic changes.

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Priority nutritional concerns in Asia

E-Siong Tee

Abstract

The sustained economic growth and increasing economic stability in the Asian region over the last three decades have been accompanied by changing lifestyles leading to significant changes in the food and nutrition issues facing Asian countries. The chronic diseases associated with excessive consumption of nutrients, especially fat, are becoming increasingly apparent. At the same time, Asia has a disproportionate share of the malnutrition problem. Underweight and stunting remain significant problems in many Asian communities, and micronutrient deficiencies of iron, iodine, and vitamin A continue to afflict large population groups. Effective data collection and analysis are essential to formulate and implement intervention programs to address both sides of the changing nutrition scenario in Asia.

Key words: Nutrition, undernutrition, overnutrition, Asia

More than three decades of sustained economic growth in the Asian region and increasing political stability in many Asian countries have brought about rapid advances in socioeconomic status. Even the least-developed countries in the region have made significant progress. Some, for example, China, are recognized as economically stable despite global economic uncertainties. Such rapid developments have brought about marked lifestyle changes, including food purchasing and consumption patterns. Significant demographic changes have also occurred. As a result, there is a definite change in the food and nutrition issues facing communities in the countries of the region.

While nutritional deficiencies in many Asian countries are slowly decreasing in magnitude, significant proportions of Asian population are now facing the other facet of the malnutrition problem: diet-related chronic diseases such as hypertension, coronary heart disease, diabetes mellitus, and certain types of cancers. Because of the different stages of socioeconomic development, the extent of both malnutrition extremes varies considerably among the different countries in the region. Asia thus needs to address both extremes of the nutrition situation.

Changes in the Asian nutrition scenario

Dramatic socioeconomic developments over the past 30 years have brought about increased nutrient availability in many countries in the region as well as improved health facilities. These improvements have led to improvements in morbidity and mortality and a marked decrease in nutrient deficiencies. Nevertheless, the extent of the undernutrition problem is still large, and the magnitude varies markedly among the countries in the region.

In addition to changes in the amounts of available nutrients in Asian countries, there have been marked changes in the sources of nutrients and the composition of diets. Significant changes in consumption patterns in Asian countries occurred from 1960 to 1990. Cereal consumption decreased in most countries, except in the low-income countries, where average consumption has remained more or less stable. There also have been increases in the percentage of energy from fat, and there has been an increased consumption of added fats in most countries. The most affluent countries show an increase in vegetable and fruit consumption. Meat consumption (and thus the consumption of saturated animal fat) has increased markedly in some countries; for example, Japan, China, and South Korea recorded increases of 250% to 330%. Consumption of milk and dairy products has increased in only a few countries [1].

There have also been other changes in dietary behav-

The author is affiliated with the Cardiovascular, Diabetes and Nutrition Research Centre, Institute for Medical Research, Kuala Lumpur, Malaysia.

ior. More families eat out, and the consumption of fried foods is increasing. Overeating is a concern among some. The use of dietary supplements is also increasing, and some individuals have the mistaken belief that supplements can replace missed meals. Other significant lifestyle changes have also taken place, including decreased physical activity, even in rural areas. The high prevalence of smoking in the region, however, remains unchanged.

The combined effect of these lifestyle changes is causing a significant change in the food and nutrition issues facing Asian countries. Of growing concern are the significant proportions of the population now faced with the other facet of the malnutrition problem: the chronic diseases associated with excessive consumption of various nutrients (e.g., fat), on the one hand, and low levels of intake of other nutrients (e.g., complex carbohydrates and fiber) on the other. The increased prominence of these diseases is evident in the mortality and epidemiologic data, which vary markedly among countries in the region. On the one hand, for the most developed countries, such as Japan and South Korea, the problem of diet-related chronic diseases predominates. On the other hand, less-developed countries in South Asia and the Indo-Chinese countries are burdened with a greater share of the undernutrition problem. Between these two extremes, China and most countries in Southeast Asia are faced with a significant chronic disease problem while also struggling with the persistent nutrient deficiencies that persist to some extent. These new dimensions in the nutrition situation in developing countries pose great challenges to nutritionists and other health workers.

Undernutrition: a huge and persistent problem in Asia

In spite of the economic advances in the region, undernutrition, including underweight and stunting, remains a significant problem in many Asian communities. Micronutrient deficiencies, especially those that result in iron-deficiency anemia, iodine-deficiency disorders, and vitamin A–deficiency disorders, afflict large population groups, especially young children [2–7].

Indeed, Asia has a disproportionate share of the malnutrition problem, where the number of malnourished children is mind-boggling. In 1980 there were 174 million stunted preschool children in Asia, constituting more than three-quarters (78.3%) of the stunted children in all developing countries. In 2000, this total declined to 128 million, but Asia still had two-thirds (70%) of the developing countries' stunted preschool children. In 1980, 52% of Asian preschool children were stunted—the highest rate of any region in the world. This figure has steadily declined, and in 2000, 34% of Asian preschool children were stunted.

A similar picture is presented for underweight preschool children in Asia. In 1980, there were 146 million underweight preschool children in Asia, constituting 83% of the underweight preschool children in developing countries. In 2000, the number declined to 108 million, or 72% of the total of underweight preschool children in all developing countries. The prevalence of underweight preschool children in Asia, 44%, was the highest of any region of the world in 1980, although it declined to 29% in 2000.

Iron-deficiency anemia also affects large numbers of Asians. Among preschool children, the prevalence of anemia is reported to be the highest in Africa and Asia. In Asia, the most affected subregion is South Central Asia, where the prevalence can be as high as 60%. Among pregnant women, Africa and Asia again have the highest prevalence of anemia. Anemia prevalences are as high as 75% in South Central Asia. Among school-age children, the prevalence of anemia is highest in Southeast Asia, where as many as 60% of children may be affected.

Huge numbers are similarly affected by iodine-deficiency disorders in Asia. In the Southeast Asian region alone, nine countries have been recognized as having iodine-deficiency disorders as a public health problem. A total of 172 million people, or 12% of the population, are affected by goiter, and another 41% are at risk for the disorder.

Vitamin A deficiency also remains a problem of immense magnitude, although data are not available to make good estimates of the extent of the problem. It is clear, however, that subclinical vitamin A deficiency in Asia should not be ignored.

Because the extent of the undernutrition problem remains huge, it is vital that actions be undertaken to tackle undernutrition-related issues. More thought should be given to implementing programs and activities relevant to local communities. Food fortification, supplementation in some cases, and efforts to increase food availability have all been tried in Asia with varying success. Nutrition education efforts have been going on in the region for three decades. Other factors related to malnutrition should be tackled at the same time, specifically environmental sanitation. The importance of infection should not be neglected.

Overnutrition: a major problem on the horizon

Dramatic changes in socioeconomic conditions in the Asian region are expected to continue in the future. The associated increase in diet-related chronic diseases in developing countries in Asia should be a cause for real concern and for concerted interventions. For countries not yet afflicted with diet-related chronic diseases, it is important to avoid or reduce the onslaught of these diseases. It is hoped that these countries will be able to learn from the mistakes of others, and not follow the same path.

The emerging problem of overweight in children cannot be ignored. The current proportion of overweight preschool children in developing countries is low, estimated to be 3.3% in 1995. There is, of course, considerable variation in this prevalence. The estimate for Asia was 2.9%, with a higher prevalence of 4.3% in Eastern Asia and 2.4% in Southeast Asia [8]. Data from individual Asian countries show higher proportions in Brunei Darussalam (9%), in Thailand (5.4%), among urban children in Kuala Lumpur (8%), and among urban children in China (6.5%). A total of 17.6 million preschool children in all developing countries were considered overweight. Of this total, 61%, or 10.6 million, were in Asia. The region therefore has the double burden of the highest number of stunted preschool children and the highest number of overweight children.

The problem of increasing overweight and obesity in Asian adults has been highlighted for more than a decade. The database on the extent of the problem is far from comprehensive, but various studies point to the severity of the problem. In Malaysia, the available data indicate that in urban communities the overall prevalence of overweight is probably about 29% and that of obesity about 12%. The combined prevalence of overweight and obesity (body mass index [BMI, expressed in kg/m^2] > 25) in Malaysia ranged from 26% to 53%, with an overall mean of 39%. The problem also appears to be prevalent in lower-income urban adults and in rural communities [7]. In a study of a small number of urban subjects in 12 Asian cities, the prevalence of overweight and obesity (BMI > 25) was found to be high (more than 23%) in 5 cities: Beijing, Hong Kong, Kuala Lumpur, Manila, and Bangkok. It was also noted that the most affluent societies in the study, for example, Seoul and Tokyo, did not have the highest prevalence of overweight.* In China, national nutrition surveys conducted in 1982 and 1992 showed that the prevalence of overweight and obesity in young adults increased from 9.7% to 14.9% in urban areas and from 6.2% to 8.4% in rural areas during the 10-year period [5].

Much of the overweight and obesity problem described occurs in urban areas. For example, in a study of more than 5,000 primary schoolchildren in Kuala Lumpur, the prevalence of overweight was 8%, much higher than that in a similarly large study in rural areas in the other parts of Malaysia, which reported a prevalence of 2% [7]. However, several reports in recent years have also highlighted the increasing prevalence of the problem in rural areas.

The high prevalence of overweight and obesity is associated with increases in a whole host of diet-related chronic diseases in many communities in the Asian region. Coronary heart disease has been reported to be a main cause of death in many countries, and the prevalence of hypertension and diabetes has reached worrying proportions.

It is imperative that the problems associated with diet-related chronic diseases be identified and recognized early enough for firm actions to be taken immediately. It is indeed a challenge for governments to formulate intervention programs to tackle both facets of the malnutrition problem. Several governments in Asia have carried out interventions focusing on healthier lifestyles, including healthy eating. Some communities are earnestly seeking ways to achieve healthy eating, including healthier food alternatives and health supplements, whereas others are not. The extent of the diseases is certainly not decreasing. Thus, what works and what does not, and what works where, are going to be important questions to answer.

Other nutritional concerns

Other nutritional concerns are the continued high prevalence of low birthweight, adolescent nutrition issues, and interactions between nutrition and infection. As the aging population of Asia increases markedly in the coming years, the nutritional needs of the elderly will be important issues to address.

Economic progress in the countries of the region will continue to be accompanied by lifestyle changes. It is therefore of the utmost importance to continue to monitor nutritional status. Systems to periodically collect data on nutritional status and dietary intakes should be in place in all countries. Indeed, comprehensive data specific to the communities concerned should be made available through systematic research programs to permit the formulation and effective implementation of intervention programs in developing countries. All countries in the region need to develop a national plan of action for nutrition, jointly formulated and implemented by all of the relevant sectors, including food, health, and education. Such plans should be periodically reviewed.

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Food security in Latin America

Adolfo Chávez and Miriam Muñoz

Abstract

Although the nutrition situation in most Latin American countries is improving and malnutrition is easing, worrisome factors are emerging. Huge rural-to-urban migrations have been accompanied by a worsening nutrition situation in rural populations, especially in Mexico, Colombia, and Brazil, a phenomenon not readily apparent from average food availability and malnutrition data. Average figures can also mask the severe nutrition problems that persist in four densely populated areas: the Caribbean Islands, Central America, the Andean region, and parts of Brazil. Although globalization is improving the nutritional status of many population groups in Latin America, it is also creating new pressures. Latin American countries dependent on agriculture are especially vulnerable.

Key words: Nutrition, food security, Latin America

The recent food balance sheets from the Food and Agriculture Organization of the United Nations (FAO) show that food availability has increased in most Latin American countries. The average intake of calories per person per day for the region as a whole increased from 2,285 in 1980 to 2,700 in 2001 [1]. Similar improvement has been reported for malnutrition by the Pan American Health Organization, with weight-for-age in preschoolers as the indicator [2]. Some countries, such as Brazil, Colombia, and Mexico, have almost halved their proportions of malnourished people over the past 20 years. In an even shorter period, 11 years (1985–1993), the official figures dropped from 16.2% to 9.0% [3]. The same types of improvements are also being reported for some specific micronutrient deficiencies, mainly those of iodine and vitamin A.

Aldolfo Chávez is affiliated with the Instituto Nacional de Ciencias Médicas y Nutrición, Mexico 14,000 D.F., Mexico. Miriam Muñoz is affiliated with the Universidad Autonoma de Morelos, Cuernavaca, Mexico

Regardless of the improvements, there are some worrisome data and other concerns about food security because of the agricultural and economic situation in the region. It is unclear whether the optimistic figures published by the United Nations agencies [1, 2] reflect what is actually occurring in Latin America. The huge migrations from rural to urban areas and some of the survival strategies of the poor are important factors in the region. For example, in Mexico unofficial surveys done by our research group show overall national improvement, but not as great as reported above [4, 5]. The improvement is explained by the change in the proportions of the rural and urban populations. The prevalence of malnutrition in rural areas actually worsened, increasing from 16% in 1980 to 19.8% in 2001, but its impact on the national figures was low because only 24% of the population is rural. The situation is similar in Brazil and Colombia, two of the largest countries in South America.

In two conferences held in 2001, the change in food security in Latin America was emphasized, and natural and socioeconomic factors were discussed [6, 7]. Of the natural factors, the contamination of surface and underground water, land erosion, and the high frequency of disasters were emphasized. However, more importance was given to the lack of agricultural financing, cuts in subsidies, the low prices of most commodities, competitive factors caused by the globalization of the marketplace, the low purchasing power of much of the population, and other socioeconomic factors. Together they constitute a pending crisis for Latin American agriculture and rural development.

Many Latin American experts concur on the major role of international globalization in creating competitive large companies, with their sophisticated technology, management, and financial systems, as compared with the less sophisticated production systems of Latin America. There is a preference in local markets for imported products from these large suppliers, which accounts for the increasing globalization of local commercial organizations.

The lack of agreement on Latin American figures for food availability and malnutrition can be explained in part by the probability that the average figures are hiding a phenomenon common to most countries: the contrasting situation in different regions and population groups. Severe problems persist in four densely populated areas [7]: the Caribbean Islands (Haiti, the Dominican Republic, and Cuba), Central America (southeastern Mexico, Guatemala, Honduras, El Salvador, and Nicaragua), the Andean region (Ecuador, Bolivia, and Peru), and the northern, northeastern, and western regions of Brazil. The rest of Latin America has local or regional problems, but the high demand for food elsewhere and the capacity to import food explain the high food availability figures published by the FAO.

Another nutritional problem in all of Latin America is, with few exceptions, as widespread as malnutrition: the tendency of the population to suffer from obesity, insulin resistance, and the chronic clinical syndromes linked to them—diabetes, hypertension, and cardiovascular problems. It is now known that populations of Indo-American ancestry tend to have the so-called thrifty gene, and that early malnutrition, from the womb to three years of age, predisposes them later to these chronic syndromes. Thus, in some communities or families, the children are at risk for malnutrition, while the adults are at risk for these chronic diseases.

The reality over the past 20 years of economic change and globalization is that most Latin American countries, and some regions especially, are struggling to cope with the new socioeconomic conditions, and that the situation must not be allowed to worsen. It is also true that Latin American agriculture is suffering and that the countries and regions that depend on agriculture are on the brink of crisis, with the near future difficult to predict.

International economic pressures surely will continue, and the new global market will be progressively more dominant. In the absence of other solutions, the ability of Latin American societies to adapt to and to adopt the new economic and technological conditions will be the key not only to their progress in the new globalized world but also to their very survival.

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Three criteria for establishing the usefulness of biotechnology for reducing micronutrient malnutrition

Howarth E. Bouis

Abstract

The fundamental reason that plant breeding using either conventional breeding or biotechnology is so cost-effective is that the benefits of a one-time investment at a central research location can be multiplied over time across nations all over the world. Supplementation and fortification incur the same recurrent costs year after year in country after country. However, each intervention has its own comparative advantages, such that a combination of several interventions is required to substantially reduce micronutrient malnutrition. Improving the density of trace minerals in plants also reduces input requirements and raises crop yields. A simulation model for India and Bangladesh demonstrated that $42 million invested in conventional breeding in developing and planting iron- and zinc-dense varieties of rice and wheat on only 10% of the acreage used for these crops would return $4.9 billion in improved nutrition (including a total of 44 million prevented cases of anemia over 10 years) and higher agricultural productivity.

Key words: Biotechnology, nutrition, micronutrient malnutrition

The potential usefulness of biotechnology in providing more nutritious food staples in developing countries depends on meeting three general criteria.

First, it must be established that plant breeding is more cost-effective than alternative interventions already in place to reduce micronutrient malnutrition. This is apparently the case, in large measure because of the multiplier effects of plant breeding: a relatively small, fixed initial investment in research may benefit the health of millions of poor people in developing countries all over the world and, at the same time, may improve agricultural productivity on lands that are presently among the least productive.

Second, there must be aspects of the breeding strategy for which biotechnology is superior to traditional breeding techniques. For example, this is the case for adding β-carotene-related and heat-stable phytase genes to rice. In the long run, as more is understood about the factors driving the translocation of minerals in plants, it may also be the case for increasing trace mineral density.

Third, for those aspects of the plant-breeding strategy for which biotechnology is superior to conventional plant breeding, it must be established that:

» there are no serious, negative agronomic consequences associated with the characteristic being added;
» consumers will accept any noticeable changes in the color, taste, texture, cooking qualities, and other features associated with the characteristic being added;
» the characteristic being added will result in a measurable improvement in the nutritional status of the malnourished target population; and
» biofortified transgenic crops are safe to eat.

The conditions for the third criterion, in particular, have yet to be firmly established. However, it is important not to be overly cautious. The potentially enormous benefits of biotechnology to the poor in developing countries in relation to costs are so high that research in this area should be vigorously pursued [1].

The comparative advantages of a plant-breeding approach

The fundamental underlying cause of micronutrient malnutrition is that agricultural systems are not producing sufficient vitamin- and mineral-rich foods such as fruits, meat, fish, legumes, and vegetables that the poor want to eat but simply cannot afford to purchase. It is essential that some activities with longer-term payoffs and lower costs address the root cause at the same

The author is affiliated with the International Food Policy Research Institute in Washington, DC.

time that shorter-term measures are taken to relieve suffering and improve lives as quickly as possible. This dual approach is highly complementary.

We all envision a future when nutrition education and increased incomes of the poor will be combined with greater availability and lower food prices to improve dietary quality. However, this will require the eventual investment of many billions of dollars by small farmers, the business sector, and governments over several decades to increase the production and availability of these nutrient-rich, nonstaple foods. In the meantime, specific agricultural strategies can be implemented to improve nutritional status. One of these is "biofortification"—breeding for micronutrient-dense staple food crops, a strategy of getting plants to fortify themselves.

The fundamental reason that plant breeding is so cost-effective is that the benefits of a one-time investment at a central research location can be multiplied over time across nations all over the world. Other interventions incur the same recurrent costs year after year in country after country. Table 1 provides a comparison of the nutritional benefits that $80 million can purchase through programs of supplementation, fortification, and plant breeding and biofortification [2].

Moreover, recent research has demonstrated that improving the density of trace minerals in plants is beneficial for crop nutrition as well, reducing input requirements and raising crop yields. Thus, biofortification has a dual benefit for public health and for farm productivity, so that investments in this area have a particularly high payoff. For example, seeds of lines of wheat and rice bred to be high in zinc content have a higher survival rate, and initial growth is more rapid. Ultimately, yields are higher, particularly in poor soils in arid regions. Crop lines with roots that are efficient in taking up trace minerals from soils resist disease better, and the roots extend more deeply into the soil and can thus tap more subsoil moisture and nutrients. Consequently, these lines are more drought resistant and require less irrigation. Because of their more efficient uptake of existing trace minerals, these varieties also require fewer chemical inputs. Thus the new seeds can be expected to be environmentally beneficial as well. The benefits for agricultural productivity and environmental sustainability are a highly desirable complementary aspect of breeding for trace mineral density, which further enhances the cost-effectiveness of biofortification [3, 4].

A further comparative strength of biofortification is that it can reach the malnourished in relatively remote rural areas where commercial markets are least developed. Biofortification is therefore highly complementary with conventional fortification, which works best in urban settings where markets are better developed.

Biofortification seeks to take advantage of existing consumer and farmer behavior. Increasing the iron and zinc density of the most widely grown and consumed crop lines would not change the color and taste of staple foods, which poor women and children already eat in large amounts day after day. Farmers would choose to grow these nutritionally enhanced lines because of their high profitability.

Benefit-cost analysis

A simulation model has been developed for India and Bangladesh to demonstrate the enormous economic benefits of the biofortification strategy. This model assumes that iron- and zinc-dense varieties of rice and wheat developed under a proposed project are adopted on only 10% of approximately 83 million hectares planted with rice and wheat. The somewhat conservative assumptions suggest that the returns that come during the second decade of research and development (years 11–20 of the simulation model) would be about $4.9 billion on a total investment of $42 million: $1.2 billion in benefits from better nutrition and $3.7 billion in benefits from higher agricultural productivity.

A more formal benefit-cost analysis, using a 3% discount rate (commonly used for analysis of social benefits), gives a benefit-cost ratio (present value of benefits divided by present value of costs) of 19 for returns to better iron nutrition. This ratio rises to 79 if benefits to higher agricultural productivity are included. A different way of expressing the concept of discounting over time is the internal rate of return, the interest rate

TABLE 1. Comparison of an investment of $80 million across interventions

Supplementation	Fortification	Plant breeding/biofortification
Provide vitamin A supplementation to 80 million women and children in South Asia (1/15 of the total population) for 2 years, at a cost of 50 cents for 2 pills, each effective for 6 months	Provide iron fortification to 33% of the population in South Asia for 2 years. Costs of fortification estimated as 10 cents per person per year	Develop 6 nutrient-dense staple crops for dissemination to all the world's people for consumption year after year. This includes dissemination and evaluation of nutritional impact in selected countries Establish prebreeding knowledge base for 9 additional staple crops important in the diets of the poor

at which the benefits would equal the direct costs plus interest if the funds were borrowed to make the investment. In this case, the annual internal rate of return is 29% if only benefits to human nutrition are considered, and 44% if both benefits to human nutrition and higher agricultural productivity are considered.

In the longer term (years 11–25 of the simulation), it is estimated that a total of 44 million cases of anemia will be prevented annually. This is based on a conservative assumption of only a 3% reduction in anemia among those consuming the high-iron rice. This works out to cost of about US$1 per annual case of anemia prevented and an annual cost of 3 cents per person reached, whose iron (and zinc) intakes increase by 50% through consumption of the biofortified rice and wheat [5].

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The promise of biotechnology in addressing current nutritional problems in developing countries

Gurdev S. Khush

Abstract

To meet the nutritional needs of a rapidly growing world population, which is likely to reach 8 billion by 2030, 50% more food grains with higher and more stable yields must be produced. Biofortification is considered the most effective way to increase micronutrient intakes. It is low cost and sustainable and does not require a change in eating habits or impose recurring costs. A research project to improve the iron and zinc content of rice was initiated at the International Rice Research Institute in 1992. Several experimental lines of rice with increased iron and zinc content have been produced. In another experiment rices with β-carotene have been produced. Other experimental efforts aim at raising the micronutrient content in wheat, maize, cassava, sweet potatoes, and beans. Maize with improved amino acid balance is being grown in several African countries.

Key words: Biotechnology, nutrition, biofortification, micronutrient malnutrition

Access to a healthy diet is a fundamental right of every human being, yet 800 million people, mostly in the developing world, go to bed hungry every night. Furthermore, micronutrient deficiencies, which affect 3 billion people, hinder the development of human potential and the social and economic development of nations.

Access to food depends on income. Currently, more than 1.3 billion people in the world are extremely poor, with incomes of less than US$1 per person per day, and another 2 billion are only marginally better off [1]. Thus, investments in employment generation are as important as investments in food production.

The malnutrition problem is further exacerbated by increases in the world population, which is likely to reach 8 billion by 2030. Most of this increase (93%) will take place in the developing world, whose share of the global population is projected to increase from 78% in 1995 to 83% in 2020. To meet the challenge of feeding an ever-increasing population and alleviating protein–energy malnutrition, we will have to produce 50% more food grains. To meet this challenge, we will need crop varieties with higher and more stable potential yields. Conventional plant-breeding as well as biotechnology techniques will be employed to develop crop varieties with higher yields and greater resistance to diseases and insects.

Tackling micronutrient malnutrition

In addition to protein–energy malnutrition, deficiencies of minerals and vitamins affect a high proportion of the world's poor. Deficiencies of iron, zinc, iodine, and vitamin A are most acute. An estimated 2 billion people in the world are iron deficient. At least 400 million are deficient in vitamin A, 100 million of whom are young children. As many as 3 million children die annually as a result of vitamin A deficiency [2]. One billion people live in iodine-deficient regions, and many of them suffer from iodine-deficiency disorders, including goiter, cretinism, lower intelligence, and increased prenatal mortality [3]. Zinc deficiency, which is thought to be widespread, can lead to retarded growth, depressed immune function, anorexia, dermatitis, skeletal abnormalities, and child mortality if prolonged [4]. Furthermore, zinc deficiency has been linked to underutilization of vitamin A. Even in developed countries, micronutrient deficiencies affect a significant number of people. Taken together, micronutrient deficiencies affect a far greater number of the world's population than does protein–energy malnutrition [5].

Intervention programs for alleviating micronutrient malnutrition include supplementation, food fortification, education, and biofortification. Fortification programs have been successful in reducing malnutrition

The author is affiliated with the International Rice Research Institute, Los Baños, Laguna, Philippines.

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in specific situations, for example, fortification with iodine through the use of iodated salt. However, for iron, zinc, and vitamin A, fortification and supplementation programs are expensive, incur ongoing costs, and are unlikely to reach all of those at risk. Moreover, such intervention programs have often been suspended for economic, political, or logistical reasons [6].

One approach to solving the problem of micronutrient deficiencies is to persuade people to make their diets more nutritious. However, attempts to change eating behavior are generally unsuccessful. It is often difficult for poor people to make dietary changes using local food. These attempts require a lot of input, constant follow-up, and education. When they are scaled up, they rarely work, so they tend not to be sustainable.

Under these limitations, biofortification is considered the most effective way to tackle micronutrient malnutrition. This strategy for supplying micronutrients to the poor in developing countries involves making staple foods eaten by the poor more nutritious by using conventional plant breeding and biotechnology. This strategy is low cost and sustainable, and it does not require a change in eating habits and does not impose the recurring costs that accompany food supplementation and fortification.

Increasing the mineral and vitamin concentration of staple crops

The main concern about the potential benefits of using mineral- or vitamin-dense staple crops is whether the increased concentrations will in fact result in significant increases in bioavailable minerals and vitamins and, consequently, improve the nutritional status of malnourished populations. For this to happen, vulnerable groups have to consume the improved varieties of staple crops in sufficient quantities.

Even more important, the net amounts of bioavailable nutrients they ingest must be greater than those in traditional crops. For example, the main sources of iron for impoverished populations are staple cereals and starchy roots, tubers, and legumes, but most of the iron ingested from these sources has low bioavailability. It is estimated that cereals contribute up to 50% of iron intake in households from lower socioeconomic groups [7]. For zinc, the contribution from plant sources can be as high as 80%. This means that doubling the iron and zinc density of food staples could increase the total intake by at least 50%. The main problem, however, is that diets based on plant staples usually contain large amounts of phytic acid [6], which inhibits iron and zinc absorption. Thus, crop-improvement strategies should aim at increasing the level of micronutrients, on the one hand, and reducing the amount of phytic acid, on the other.

Improving the amount and bioavailability of iron and zinc

A research project to develop improved rice varieties with high iron and zinc content was initiated at the International Rice Research Institute (IRRI) in 1992. Considerable variation in both iron and zinc was observed in the rice germplasm. Iron concentrations ranged from 6.3 to 24.4 mg/kg, with a mean value of 12.2 mg/kg. For zinc, the range was 15.3 to 58.4 mg/kg [8].

Efforts are under way to develop improved rice germplasm with elevated levels of iron and zinc. Crosses between traditional varieties and high-yielding varieties have produced progenies with both high yield and high micronutrient levels. For example, an improved breeding line, IR68144, has both a high concentration of iron in grain (about 21 mg/kg) and a high yield potential. Milled rice of this variety is being used in human feeding trials to determine the bioavailability of the iron [8].

A genetic engineering approach has been successfully applied to raise the iron content of rice. Goto et al. transferred the soybean ferritin gene into the Kita-ake rice variety through transformation [9]. The iron content of the transgenic seeds was as much as threefold greater than that of untransformed seeds. Similarly, Lucca et al. introduced the ferritin gene from the common bean into rice, and the transgenic lines had twice as much iron as controls [10]. To increase the bioavailability of iron, Lucca et al. introduced the thermotolerant phytase gene from a fungus into the rice endosperm to break down phytic acid, thus improving the bioavailability of the iron in rice [10]. Mutants of barley, maize, and wheat with low amounts of phytate are available and may be employed to develop varieties of these crops with improved iron bioavailability.

Ortiz-Monasterio found a fourfold variation between the lowest and highest concentrations of iron and zinc in the grains of several hundred wheat accessions [11]. Studies at the International Center for Tropical Agriculture showed that certain varieties of common bean had 60% to 80% more zinc than other widely grown varieties. Breeding efforts are under way to incorporate high levels of zinc into improved varieties [12].

Improving the vitamin A content of crops

β-Carotene, a precursor of vitamin A, does not occur naturally in the endosperm of rice. Therefore, populations that derive most of their calories from rice suffer from vitamin A deficiency. The poor people in many Asian countries (Vietnam, Laos, Cambodia, Myanmar, Bangladesh, and India) derive more than 60% of their calories from rice.

Ye et al. introduced two genes from daffodil (*Narcissus pseudonarcissus*) and one gene from a bacterium (*Ervinia uredovora*) into rice variety Taipei 309 through genetic engineering [13]. Ten plants had a yellow endosperm (because of the presence of β-carotene), had a normal vegetative phenotype, and were fully fertile. Taipei 309 was used to introduce the β-carotene biosynthetic pathway, which is easy to transform. However, Taipei 309 is no longer cultivated. IRRI has started a project with the aim of introducing the genes for β-carotene production into widely grown improved varieties through transformation as well as through conventional hybridization techniques. It is anticipated that improved rice varieties containing β-carotene will become available during the next two to three years.

Strong carotenoid pigmentation was present in older wheat varieties used for bread. However, during the twentieth century, market demand drove wheat breeding to focus on the production of wheat varieties for white flour. The pigmented-type wheat varieties can be brought back into breeding programs if desired. There also are high-β-carotene maize types (yellow maize) that are high yielding. However, in many cultures, consumers prefer white maize, which lacks carotenoids and is nutritionally inferior. Education programs should be undertaken to popularize the use of yellow maize.

Cassava is an important staple food for 50 million poor people. Genetic variation in cassava roots for β-carotene content is high. Orange-colored roots have 9 to 10 times more β-carotene than white roots. There is thus an obvious advantage in popularizing the use of orange-colored varieties of cassava.

An action research project was recently implemented by the Kenya Agricultural Research Institute in Nairobi in collaboration with the International Potato Center in Lima, Peru. Orange-fleshed varieties of sweet potatoes that were both high yielding and rich in β-carotene were introduced to women farmers. The orange-fleshed sweet potatoes, both when eaten alone and when consumed as ingredients in processed foods, were highly acceptable to both producers and consumers. Using standard methods of analysis, it was demonstrated that their increased consumption contributed to the alleviation of vitamin A deficiency in case study households [14]. In sub-Saharan Africa, sweet potatoes are an important source of calories for poor people, but most of the sweet potato varieties grown there have white flesh and therefore lack β-carotene. The introduction of orange-fleshed sweet potatoes should receive priority.

Improving the amino acid balance

A human diet derived from cereal grains is deficient in some of the 10 essential amino acids, especially lysine, that are required for normal growth and development. Natural variation in the maize germplasm was exploited to develop quality protein maize (QPM) at the International Maize and Wheat Improvement Center (Mexico). The opaque 2 gene was incorporated into improved maize germplasm, and it doubled the amount of lysine and tryptophan. QPM maize varieties have been released in several countries and are now grown on almost 1 million hectares, and the area under QPM maize cultivation is also increasing.

Biotechnology approaches are also being used to enhance the lysine content of rapeseed (canola), corn, and soybean. The introduction of two bacterial genes for dihydrodipicolinic acid and aspartokinase enzymes encoded by the *dapA* gene from *Corynebacterium* and the *lysC* gene from *Escherichia coli* led to a fivefold increase in lysine in canola, corn, and soybean [15]. Similarly, the amino acid profile and total protein content of potato were improved through the introduction of the *AmA1* gene from *Amaranthus hypochondriacus* [16].

Conclusions

The use of biotechnology is proving to be important in improving germplasm to alleviate the malnutrition that affects almost half of the world's people. Linking agriculture and nutrition to promote dietary change and improve nutritional status can generate wide social as well as economic benefits.

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Can biotechnology help meet the nutrition challenge in sub-Saharan Africa?

Julia Tagwireyi

Abstract

The successful efforts in the 1980s to redress nutrition problems in sub-Saharan Africa are being eroded. Countries in eastern and southern Africa are now facing serious food shortages because of recurrent droughts, floods, civil wars, and the concomitant growing poverty. The potential for biotechnology to alleviate hunger holds promise if the new technology can be adapted to the prevailing sociocultural context in Africa. Agronomists and biotechnologists need to work together to ensure that the biotechnology agenda for Africa is responsive to the food and nutrition needs of its people.

Key words: Biotechnology, nutrition, sub-Saharan Africa

The nutrition situation in sub-Saharan Africa is deteriorating, especially in the Greater Horn region (Somalia and Sudan). Countries in eastern and southern Africa are facing serious food shortages as a result of recurrent droughts, floods, civil wars, and the concomitant growing poverty. Thirty-three percent of children less than five years of age are undernourished, and 50% of all deaths in these children are due to mild to moderate malnutrition. These trends have been accelerating since the early 1990s and show no sign of improvement. From 11% to 30% of adults have a low body mass index as a result of inadequate seasonal food intake, intense physical activity, and parasitic infestation. The main micronutrient-related problems of concern in sub-Saharan Africa are iron-deficiency anemia and deficiencies of iodine, vitamin A, and niacin. Niacin is of concern in countries where a predominantly maize diet is consumed. Although some progress has been made with iodine deficiency, deficiencies of the other micronutrients remain a public health problem.

Diet-related chronic diseases are now also prevalent in sub-Saharan Africa. Africa thus has to deal with the double burden of diet-related chronic disorders as well as the traditional nutrition problems and infectious diseases.

Efforts to redress nutrition problems in sub-Saharan Africa were successful during the 1980s, when several countries managed to reduce the prevalence of protein–energy malnutrition. These gains were the result of multipronged strategies characterized by large-scale community-based nutrition programs that focused on growth promotion in children less than five years of age, an effective primary health-care strategy. Also implemented were food-based strategies that promoted appropriate household food security strategies as well as food distribution programs to vulnerable communities during droughts. Food fortification with micronutrients such as vitamin A and the B-complex vitamins was undertaken in the 1990s. The multisectoral dimensions of the nutrition problem were well recognized. Several countries developed national food and nutrition policies and strategies to harness the involvement of all relevant stakeholders in the fight against malnutrition.*

Sadly, the gains made in the 1980s have been largely eroded, for several reasons, including a decline in public sector investment, which has been a hallmark of economic reform programs in Africa. Nutrition improvement in sub-Saharan Africa faces many challenges, including poverty, the growing disease burden, especially that from HIV/AIDS, and deteriorating economies with concomitant reduced public sector expenditures affecting nutrition programming. Challenges to food production include the HIV/AIDS pandemic (which is reducing the numbers of productive members of communities and eroding the intellectual capital of most developing countries in sub-Saharan Africa) [1], climatic changes resulting in environmental

The author is affiliated with the Ministry of Finance and Economic Development in Harare, Zimbabwe.

* Food and Agriculture Organization /World Health Organization. Unpublished report of the Inter-country Workshop on Follow-up to the International Conference on Nutrition, 20–23 March 2001, Harare, Zimbabwe.

degradation, the high input costs of new seed varieties, and disruption from civil wars.

Can biotechnology provide some solutions to the growing nutrition problem in sub-Saharan Africa? The potential seems to be there if the technology can be adapted to the prevailing sociocultural context as well as the prevailing nutrition problems in the region. To be successful, biotechnology approaches should be implemented within the framework of existing national priorities and strategies for food security and nutrition.

There are several barriers to the adoption of biotechnology in developing countries. Some of them are based on inadequate information on the benefits and risks associated with the technology. Fears of safety and unknown consequences to health are arising in developing countries as the developed countries themselves are questioning the technology.* Unfortunately, most African countries involved in biotechnology research and development are implementing an agenda that was created outside of Africa and that is not addressing the pressing nutrition needs of African countries [2]. The issue of patents and property rights often dictates what and how biotechnology research is conducted in developing countries. The products of such research are commercialized and become inaccessible to the subsistence farmer in rural Africa who needs it the most. The level of investment in biotechnology research is beyond the means of most developing countries, whose research budgets have been declining over the years. Most biotechnology research undertaken in developing countries has been donor funded and may not be responding to the pressing problems in these countries.

The Green Revolution was adopted by some African countries, such as Kenya and Zimbabwe, in the 1960s. It doubled the maize yield, which was good for the farmer who could afford the inputs. The downside of the Green Revolution was that it resulted in a reduced food basket, because farmers focused on maize as a cash crop and abandoned the indigenous open-pollinated seeds, which could be reused and had better storage properties. Hybrid seed and other inputs have to be purchased each season. The traditionally practiced mixed cropping also served to fertilize soils through the nitrogen-fixing properties of legumes, thus reducing the need for commercially produced fertilizers. Mixed cropping has now been largely abandoned in favor of monocropping with hybrid seed varieties. The adoption of a monocropping farming system has contributed to a reduced diversity of food crops grown by farmers in Africa. To what extent has this development led to more nutritional problems? Furthermore, hybrid maize seed is softer and therefore easier to process, but it is more vulnerable to pests and has poor keeping qualities for the rural farmer who needs to be able to keep grain until the next harvest.*

Although the economic benefits of genetically modified crops to the farmer who can afford to adopt them are well documented, their ramifications on nutritional quality, their toxic potential, and their allergenic potential have been less well studied, but need to be. It should be noted that substances introduced via biotechnology occur naturally in some foods and that communities over time have found ways to deal with them.

Biotechnology has the potential for introducing some negative properties into foods that previously did not have them, and this is cause for concern. Biosafety standards and policies also need to take into account the nutritional ramifications of these genetically modified food products and to ensure that the potential benefits and risk to nutritional outcome are assessed [3].

The nutrition community in Africa needs to work together with agronomists and biotechnologists to ensure that the biotechnology agenda for Africa is responsive to the food and nutrition needs of its people. The biotechnology agenda for Africa also must take into account the challenges posed by the worsening nutrition situation, HIV/AIDS and other diseases, poverty, recurrent droughts, and environmental degradation if it is to be responsive to Africa's food and nutrition problems.

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Food biotechnology and nutrition in Africa: A case for Kenya

Christopher K. Ngichabe

Abstract

Household food consumption surveys indicate that the diet in Kenya is ill balanced and that many families cannot afford nutrient-rich foods such as meat and fruits. In this regard, rural populations—the majority of the Kenyan population—are much worse off than urban populations. Agriculture, the most important sector in the Kenyan economy, contributes 27% of the gross domestic product and generates 65% of the country's export earnings. Food-enhancing biotechnologies thus could increase national food yields and fill nutrition gaps by contributing to household and national food security and poverty reduction in Kenya. To overcome barriers to adopting biotechnology to improve food crops in Kenya and elsewhere in Africa, policy makers must create a receptive environment for, increase public understanding of, and stimulate investment in the new technology.

Key words: Biotechnology, nutrition, Africa, agricultural productivity

In Kenya, cereals are the main source of energy, providing almost 60% of needed calories. Other main sources are bananas and tubers. The consumption of sugar and of fats and oils is negligible from the point of view of calorie sources. Caloric need is met in approximately half of Kenyan families, with considerable variation according to the area and season of the year. The caloric supply is often poorest in eastern Kenya, and famine relief is commonly undertaken in the area. Pastoralists generally have a lower calorie intake than does the sedentary population. The quantity of animal and plant protein consumed varies according to household income. Where pulses grow, consumption is often adequate to meet the protein needs of households. The intake of animal protein also varies according to family income and usually contributes 0.5% to 10% of the total protein consumed. For the population around Lake Victoria, 25% to 33% of the protein supply often is from fish. The quality of protein, expressed as protein score, is generally below 65%.

The limiting amino acids are tryptophan and those containing sulfur. The sources of riboflavin and amino acids include cereals, legumes, and fruits, the intake of which is low in all areas. The main sources of vitamin A are green vegetables, pumpkin, tomato, yellow fruits, and milk in pastoral tribes. The intake of vitamin A is estimated to be insufficient (about 30% of the recommended amounts in all areas). Niacin is obtained mainly from maize, which provides an insufficient supply to some families. The sources of vitamin C are mainly fruits and vegetables, and intakes are low in many Kenyan families. Thiamine is obtained through the consumption of cereals and legumes, and intakes are above recommended allowances in all areas. Judging from the composition of the diet, the intake of cobalamin is probably below the daily recommended allowances. Food sources of iron include cereals, legumes, and leafy vegetables.

Data from household food consumption surveys carried out in seven locations in Kenya (three provinces), excluding pastoral areas, show that the Kenyan diet is insufficient in many respects: it does not supply nutrients in the required amounts and thus is ill balanced. There are also concerns with the nutritive value of diets, because many families cannot afford meat, fruits, and other nutrient-rich foods, particularly in rural areas; thus, a good number of these families, who constitute the majority of the population, are much worse off than those in urban populations. Dietary assessment reports show that Kenyan diets are lacking in adequate energy intakes for preschool-age children, school-age children, and adult women. Intakes of other nutrients are marginal or low for most age groups, except for ascorbic acid and thiamine.

The author is affiliated with the Kenya Agricultural Research Institute in Nairobi.

Nutrition-related diseases prevalent in Kenya

Because of these nutritional deficiencies, Kenyan children are affected by a number of nutrition-related disorders. Protein–energy malnutrition is largely responsible for the high rate of mortality and morbidity in poor children, and the problem is particularly severe in children between one and five years of age. Severe protein–energy malnutrition in children manifests as marasmus, often in newborns to one-year-olds, with marked emaciation as the striking feature. Severe protein malnutrition manifests as kwashiorkor, which may coexist with marasmus, but which usually appears at the time of weaning. Marked swelling (edema) from the lack of protein, especially of the face, abdomen, and feet, is the main feature of kwashiorkor. Both conditions—marasmus and kwashiorkor—are also characterized by stunting, diarrhea, discoloration and sparseness of the hair, discoloration and peeling of the skin, and anemia, although all of these symptoms may not be present in every case.

Vitamin A deficiency is common during the period of rapid growth. In mild forms of the deficiency, the eye conjunctiva may show a muddy discoloration. Instead of being moist and glistening, the conjunctiva may appear dry and lusterless. A characteristic feature is that at dusk the child gropes about for food on its plate. This condition is described as night-blindness, and it can be easily treated if diagnosed at this stage. In more severe forms, the cornea loses its transparency. Still later, the cornea becomes eroded, softens, and bulges. In the final stages, the cornea is ruptured and destroyed, and the lens inside may also be lost. Once the cornea is affected, even the most energetic treatment is of no avail, and permanent blindness cannot be prevented. The disease generally affects both eyes. In some fortunate children, one eye may be affected less seriously than the other, and intensive treatment may result in partial restoration of vision in at least one eye.

One of the common nutritional disorders affecting women of childbearing age in Kenya is anemia, in most cases caused by iron deficiency resulting from malaria, parasitic diseases, or other factors or conditions. Pregnancy aggravates anemia in women, and anemia in turn may deleteriously affect the course of pregnancy. Acting either directly or indirectly, anemia is a major cause of maternal mortality in Kenya. Anemia can be prevented by consuming such foodstuffs as green leafy vegetables daily.

Other food deficiency diseases include those resulting from inadequate intakes of the B-complex vitamins. For example, nicotinic acid deficiency leads to pellagra, a disease characterized by dermatitis in skin exposed to the sun. Other manifestations include diarrhea, soreness of the tongue, and some mental disorders. Foods rich in B vitamins prevent pellagra. Whole cereals and millets such as wheat, pulses, nuts, and oilseeds are rich in riboflavin and folic acid. Rice poses some B-complex nutrition problems because its nutrient-rich husk must be removed before consumption. Parboiled rice is particularly rich in thiamine, even after milling, so it would be better for rice-eating people to cook and consume parboiled rice instead of raw rice. However, in Kenya rice is not a staple food, so problems of vitamin B deficiencies are not prevalent.

Endemic goiter was found in about 30% of 28,520 schoolchildren studied between 1962 and 1964. The highland provinces of Central, Nyanza, Western, and Rift Valley are expected to have a higher incidence than the Eastern and Coast provinces. There is no doubt that increased iodine intake can counterbalance the goitrogenic effect of thiocyanates and perchlorates, but the action of thiocarbamide derivatives cannot be prevented by iodine.

Constraints to agricultural productivity

Agriculture is the largest and most important sector in Kenya's economy, providing the backbone of the nutritional and economic well-being of the people. Agriculture contributes approximately 27% of the gross domestic product and generates about 65% of all export earnings for the country. The agricultural sector employs more than 80% of the rural population. Several studies have shown that it is the most productive sector in Kenya for investment purposes, having a growth multiplier effect of 1.64, compared with an average of 1.23 for the rest of the economy. Agricultural productivity is critical to Kenya's economic performance and the improvement of the welfare of her people.

Despite the importance of the agricultural sector, its performance in the past 10 years has been disappointing. Although increased productivity is urgently required to meet the needs of an additional 10 million people in the next 25 years, Kenya's agricultural production remains uncertain and precarious. The growth rate of the agricultural sector has declined since 1989, and at this time the rate is declining.

The stagnation of agriculture in Kenya is due to many factors, including the following:

» Because of previous divisions of the family holdings, there is not enough land to produce minimal food requirements.
» The transition period from a subsistence economy to a monetary economy has not yet established an intensive exchange of goods and trade. The production for market is small, the farmer lacks cash, and there is little stimulus to produce more than the family needs.
» The slow acceptance of effective agricultural methods is facilitated by illiteracy, mainly in the older generation.

» The production of food crops in some areas is dominated by monoculture (maize, beans, cassava, and bananas), which restricts the exchange of products and their conversion into money and conserves the monotony and unhealthy composition of the diet.
» The production of animal protein among the cultivators is limited, although there are unused reserves. The cultivation of good breeds of cattle, the exploitation of fish resources, and the breeding of small domestic animals (poultry, rabbits, etc.) are practiced at very low levels.

Other considerations that are constraining Kenyan, as well as African, agricultural performance include a shortage of arable land, inadequate rainfall, poor soil fertility, pests and diseases, and a poor technological base.

Food-enhancing biotechnologies can provide opportunities for increasing national food yields and filling nutritional gaps, thereby contributing to household and national food security and even poverty reduction in Kenya. For example, a sweet potato that is resistant to a common viral disease is being field tested in Kenya. The viral infection causes a 20% to 80% crop loss. The biotechnology-derived crop should provide larger yields (at least a 15% increase) of this nutrient-rich food. The expected increase in farmer income is US$41 million annually, with up to one million people having access to the crop. The vitamin A content of these sweet potatoes may also be increased through genetic modification.*

African countries have started investing in biotechnology research and development in the past few years. Public research institutions are already involved in projects and programs to develop specific agricultural biotechnology farm products, some of which are beginning to enter the commercial market. However, the nature of activities and levels of investment in the technology varies from one country to another and from one sector to another.

African countries can be categorized into three phases of biotechnology development. The first category consists of those that are generating and commercializing biotechnology products and services using third-generation techniques of genetic engineering (i.e., using genetically modified organisms, or GMOs). Only South Africa belongs to this category at the moment. The second category consists of those that are engaged in third-generation biotechnology development but have no products yet, such as Kenya, Egypt, Zimbabwe, and Mauritius. The third category constitutes countries engaged in second-generation biotechnology, mainly tissue culture. The majority of African countries are in this category.

Barriers to the development of biotechnology in Africa

Major constraints hinder biotechnology development in Africa. What is needed is a policy environment that encourages biotechnology development, an educational effort to improve understanding of biotechnology, and policies to stimulate investment in biotechnology.

A major challenge for most African countries is how to create a positive, receptive environment to actively take advantage of biotechnology processes and applications that will increase the marginal productivity of their capital stock without compromising the health and environmental needs of society. There is an urgent need to create an enabling policy environment for the development and use of biotechnology in Africa that addresses the concerns of producers, consumers, environmentalists, trades, and others.

Producer concerns in Africa relate to the effects of inserted genes on target production constraints, costs of inputs, increased yields, and safe handling and marketing of their products. Knowledge of these issues is needed through appropriate education based on case studies.

Consumer concerns include product safety (specifically allergenicity toxicity concerns), antibiotic resistance, and cost. There is a need to train and educate consumers on the benefits and limitations of biotechnology and to strengthen biosafety systems, i.e., make them transparent and protective of the consumer. About 90% of the population in Africa have no idea how biosafety systems work, much less whether they are truly protective and provide safety assurance.

With regard to environmental risks, the major concerns are gene flow, weediness (ability to grow where not wanted) and effects on nontargets, the creation of monocultures, and impact on biodiversity. There is an urgent need for scientists in the biotechnology sector to share their knowledge and understanding of these events with environmentalists, the public, planners, and policy makers, using case studies such as those on the monarch butterfly and the grain borer to provide assurance that society and the broader environment are not put at risk by these new technologies.

Ethical issues relate to "man playing God" and to the social and cultural leanings of peoples and societies. These are not easy to handle but can still be solved through transparency-based education.

Governments, therefore, urgently need to create policies, mechanisms, and an incentive-based structure to provide insight and education to various societal groups on these issues, because they are causing apprehension and are impeding progress on biotechnology

* Wambugu F. Virus resistant sweet potato project in Kenya. Presented at a conference on "Agricultural Biotechnology, the Road to Improved Nutrition and Increased Production," held at Tufts University in Boston, Mass, USA, November 1–2, 2001.

development and trade in Africa.

A number of issues concern the level of public understanding of biotechnology that must be addressed for the successful application and use of biotechnology in Africa. These relate to a severe lack of understanding of the technology and its potential benefits and risks, as well as the challenges of dealing with the ethical aspects of biotechnology. This lack of public understanding of biotechnology and the issues surrounding it has resulted in negative backlash in many regions in the world, especially Europe. This backlash has resulted in selective trade barriers. In Africa, where the level of understanding of biotechnology is very low, a backlash could occur relatively easily. Such a situation can be solved through improved communication and better understanding of the scientific principles that underlie biotechnology. Public perception will determine the future of biotechnology. This is very crucial in Africa, where 96% of the population is ignorant about the technology. Negative media opinion and messages from antibiotechnology activist groups are, at the moment, working tirelessly to tilt the balance against biotechnology.

With regard to policies to stimulate investment in biotechnology, most countries in Africa, except South Africa, have no articulate national frameworks on biotechnology, so clear priorities and investment strategies are lacking. Biotechnology policies need to be based on clearly articulated national priorities and goals. In the absence of identified priorities, it is difficult for these countries to make informed, long-term policies.

Another policy issue relates to the long- and short-term financing of biotechnology development. Most countries in Africa invest less than US$0.5 million a year in biotechnology, although South Africa and Nigeria are investing about US$300 million and US$26 million per year, respectively. The main challenge for these countries is to find investment capital to sustain basic biotechnology development to bring laboratory findings to commercial use. Government policies to stimulate venture capital, contract research, partnerships with the corporate sector, and other forms of financing are much needed.

A third category of policy issues relates to concerns of trade and intellectual property rights. Trade concerns include the labeling of GMO products. It is difficult to contemplate how smallholder farmers in Africa will grapple with the labeling of GMO agricultural products, given the complex nature of the marketing systems. In developed countries this is more feasible, because the process is well defined from the producer to the consumer. There is an urgent need to educate the public, policy makers, and regulators about concerns such as these while there is still time.

Issues of interstate and regional trade can be solved only if member countries share a common understanding of the biotechnology issues discussed in the foregoing. It is only through such common understanding that harmonization of seed sectors and biosafety regulations can be developed to foster interregional trade through economic blocs. In Africa these include the Common Market for Eastern and Southern Africa (COMESA), the Southern African Development Coordination (SADC), and the Economic Community of West African States (ECOWAS). There is a need in Africa for education and transparency to create knowledge and trust on interstate and interregional trade issues, including intellectual property rights.

The potential for biotechnology to improve the nutritional value of cassava

Claude M. Fauquet and Nigel Taylor

Abstract

Cassava, a starch-rich plant that has poor protein content and usually poor vitamin content, feeds about 600 million people each day. When cereals can no longer be grown because of soil fertility problems, it is often still possible to grow cassava. It is the third most important source of dietary calories in the tropics, and reliance on the crop is especially high in West and Central Africa. The International Laboratory for Tropical Agricultural Biotechnology is promoting research to improve cassava productivity and is a leader in developing genetic engineering to improve the quantitative and qualitative traits of this essential food crop.

Key words: Biotechnology, nutrition, cassava, food security

In the last 30 years an average productivity increase of 2% to 5% per year was recorded for wheat, corn, and rice in tropical countries, according to the Food and Agriculture Organization of the United Nations. In the case of food crops, the increase was considerably less: cassava recorded a meager 0.7% gain and banana plantain 0%. Biotechnology can have an impact on all crops, but the biggest impact will be on vegetatively propagated crops, especially cassava. These crops are difficult or impossible to breed, so genetic engineering and mapping offer a unique possibility of integrating useful genes without disturbing the rest of the genome and thus maintaining all of the qualities of cassava roots appreciated by farmers.

Cassava: a staple food in many developing countries

Cassava (*Manihot esculenta* Crantz), also called tapioca, yucca, manioc, and mandioca, feeds about 600 million people each day, and this number is increasing at the rate of several million per year. In many instances when it is no longer possible to grow cereals for soil fertility reasons, it is still possible to grow cassava. Africa recorded a surface increase in cassava of 46% in the last 30 years. However, the productivity of cassava, with at most 15% of its potential, is one of the lowest of the tropical food crops, so the possible gain is huge. The biotic constraints on cassava are very high: viruses are prevalent in Africa and India and are a threat in South America. It is estimated that 50 million tons of cassava are not produced because of viruses in Africa alone. Biotechnology could be very instrumental not only in solving biological and genetic problems but also in responding to farmers' needs. The International Laboratory for Tropical Agricultural Biotechnology (ILTAB) is actively working to create virus-resistant cultivars appreciated by farmers. In addition, using very simple technologies, such as virus-clean in vitro propagation, could quickly and significantly impact cassava productivity.

Although cassava is cultivated mostly for human consumption, it is also used for animal feed and plays a role in the starch industry. Most of the time the roots are used, although some populations in central Africa use the top leaves. Cassava is essentially a starch-producing and starch-storing plant, with 20% to 40% of its fresh root weight being starch. Cassava roots are very poor in protein content (less than 1%) and usually very poor in vitamins, although there are cassava genotypes in South America that are extremely rich in vitamins or have high protein content. Development of biotechnological tools would allow corresponding genes to be moved to suitable genotypes.

ILTAB, at the Danforth Center, is promoting research to improve cassava productivity in developing countries, and is a leader in developing genetic engineering for cassava. ILTAB is actively working with three other founding institutions (the Centro International de Agricultura Tropical, the International Institute for Tropical Agriculture, and the Empresa Brasileña de

The authors are affiliated with the International Laboratory for Tropical Agricultural Biotechnology, Donald Danforth Plant Science Center, in St. Louis, Missouri, USA.

Investigación Agropecuaria [Brazilian Agricultural Research Corporation]) to establish a Global Cassava Plan, with the objective of raising interest and funds and increasing activities on cassava to move it from an orphan crop to an industrial crop and to better feed many millions of poor farmers and others.

The cassava crop: central to food security and microeconomics in the tropics

After rice and maize, cassava is the most important source of dietary calories in the tropics and is a central factor in food security for many of the world's poorest regions. Although Amazonian in origin, cassava is now cultivated for its starchy storage roots and leaf tissues in 100 countries worldwide and is consumed by an estimated 600 million people daily. Africa is the world's largest cassava-producing continent, accounting for 65% of the 16 million hectares cultivated worldwide and 55% of the 160 million metric tons of cassava roots harvested in 2000. Reliance on the crop is especially significant in West and Central Africa, where production can be as high as 300 kg per person per year and where, in some regions, the total area cultivated in cassava is up to 10 times greater than that of all cereals combined.

Cassava will play an increasingly important role in supplying the growing urban centers in tropical countries with low-cost food products. Fresh and processed cassava products are traded in local markets throughout the tropics, thereby generating cash for resource-poor farmers. Industrial-scale cassava plantations are well established in Thailand and are being developed in Latin America to supply the animal feed industry.

Nutritional value of cassava

Cassava is cultivated primarily for its roots, although some cultures also consume the young leaf tissues. Reports of the nutritional content of cassava products vary owing to the cultivars, the age of the plant analyzed, and the processing technologies employed. Representative values are provided in table 1.

Consumers whose diets are heavily based on cassava roots run the risk of malnutrition because of insufficient protein intake. This is especially prevalent in recently postweaned children, who are at risk of developing kwashiorkor. Poverty and low purchasing power, which limit access to quality foods to supplement a cassava-rich diet, are the underlying problem, not the crop itself.

The toxic potential of cassava is not a health issue for consumers. Cassava is infamous for containing cyanogenic glycosides, which can release hydrogen cyanide (HCN) into the body after mastication and ingestion. However, some facts regarding cassava and cyanide are that HCN compounds are an essential plant defense component, postharvest processing of roots and leaves reduces toxicity to below harmful levels, billions of people have consumed cassava over millennia without adverse effects, and HCN in cassava is problematic only when consumers are in poor health and processing is inadequate, for example, during drought, famine, and social disruption.

Opportunities for biotechnology to enhance the nutritional content of cassava

Because conventional breeding is problematic in cassava, the direct introduction of desirable characteristics through genetic engineering holds great potential for improving quantitative and qualitative traits in this essential food crop. However, the challenges are significant. Table 2 lists some desirable characteristics that might be introduced in cassava by genetic engineering, along with the challenges of meeting these short- and long-term goals.

Deploying cassava with enhanced nutritional qualities will be problematic. To improve the nutrition of large numbers of people, nutritional traits will have to be inserted into many (20 to 23) cassava cultivars,

TABLE 1. Nutritional content of cassava per 100 g of product[a]

Cassava product	Energy (kcal)	Protein (g)	Iron (mg)	Vitamin A (mg)	Vitamin C (mg)	Niacin (mg)	H_2O (%)	Fiber (g)
Root (peeled raw)	150	1.0	1.0	—	34	0.7	60	1.0
Root, dried (flour)[b]	340	1.5	2.0	—	0	0.8	12	1.5
Leaves (raw)	90	7.0	7.6	2	310	2.4	70	4.0
Leaves (dried)	190	32.5	8.0	—	—	—	27	—

a. Cassava tubers are an excellent source of carbohydrate, but they are poor in protein, vitamins, and nutrients. Processing methods (chipping and drying, soaking, and fermenting) all influence the nutritional content of processed cassava products, but detailed information is lacking. Cassava leaves are an excellent source of iron and protein, providing eight essential amino acids, and combining cassava roots and leaves provides the basis of a balanced diet.

a. Approximately 5 kg of raw peeled tubers are required to produce 1 kg of cassava flour.

and these will have to be distributed to farmers (6,000 cassava stakes are required per hectare). For farmers to adopt the improved cultivars, the plant material will need to have other, more obvious agronomic benefits, such as virus resistance. This will increase the challenge to biotechnologists

Table 2. Nutritional goals for genetically modifying cassava

Goal	Associated challenges
Ongoing and near future	
Enhance protein content of roots	Ensure an appropriate amino acid balance; ensure the nonallergenic nature of the new protein; direct the storage protein to food parts, e.g., root core, not the peel; new protein must not be destroyed or washed out during processing
Enhance vitamin A content of roots	Ensure that the vitamin survives processing and does not affect cooking qualities and palatability
Elevate iron content of roots	Direct the iron to the roots, not the leaves (which already have a high content); ensure that the elevated iron will not be destroyed or washed out during processing
Modify starch quality	The major benefits should be to the starch industry, not the small farmer
Reduce cyanogenic content of roots	May have detrimental effects on pest resistance
Longer-term goals	
Elevate dry-matter content of roots	Manipulate the source and sink (make the plant store more compounds in the root system) in the plant to direct more energy to the root system
Elevate folic acid in roots	Target the folic acid to the roots; ensure its stability during processing
Produce glutenins in roots to enhance bread-making capacity of cassava	This is a technically difficult challenge—will the cassava starch complex with glutenins?—and there are allergenic concerns

Research and development of transgenic plants in Malaysia: An example from an Asian developing country

Marzukhi Hashim, Mohamad Osman, Ruslan Abdullah, Vilasini Pillai, Umi K. Abu Bakar, Habibuddin Hashim, and Hassan Mat Daud

Abstract

In 2000, agriculture contributed 13% to the national gross domestic product of Malaysia. The country of 23 million people has created a competitive program coordinated by the Ministry of Science, Technology and the Environment, research institutions, and universities to undertake biotechnology research in several areas. Intensified research efforts are under way on oil palm, rubber, rice, papaya, and orchids. Although the most progress has been made in rice and papaya, no transgenic crop is ready for field trials. Nonetheless, preliminary steps have been taken to prepare for the trials, and detailed testing protocols are being developed.

Key words: Biotechnology, transgenic plants, Malaysia

The production of transgenic crops that have higher yields, are more nutritious, and have greater resistance to pests, diseases, and adverse environmental conditions heralds a revolution in crop improvement. Transgenic technology offers the opportunity to develop better crops beyond species boundaries with unprecedented power and precision. It also greatly extends our understanding of crop biology and provides us with cutting-edge tools to improve crops and ensure bountiful harvests beyond the conventional means.

Current status of transgenic crops in the world

In 1999, approximately 40 million hectares of transgenic crops were grown worldwide (excluding China), about 72% of which were in the United States. The other major growers were Argentina (17%), Canada (10%), and China, with significant expansion in Australia and South Africa. Between 1996 and 2000, 12 countries—eight industrial and four developing—contributed to a more than 20-fold increase in the global area planted in transgenic crops. As a result of intensive biotechnological research worldwide, many potential transgenic crops are now in the pipeline and are being tested in contained experiments, either in laboratories and greenhouses or in field trials. The markets of countries that have not yet planted transgenic crops have probably already received products from transgenic crops from other countries.

The seven most important transgenic crops grown commercially in 1999 were soybean, corn/maize, cotton, canola/rapeseed, potato, squash, and papaya. Transgenic soybean and corn continued to be ranked first and second in terms of the global area planted in transgenic crops.

The relative ranking of the major transgenic traits in 1999 was essentially the same as that in 1998: herbicide tolerance was the highest, at 71% of the global area, followed by insect resistance, at 22%. The use of stacked genes for insect resistance and herbicide tolerance in both corn and cotton recently increased significantly in the United States.

Transgenic crops in Asian developing countries

China is one of a handful of developing countries in Asia that have advanced in biotechnology research, field release, and commercialization of genetically modified organisms (GMOs). In recent years, China has intensified its research on transgenic crops and has made tremendous progress in adopting and commercializing them. In fact, China currently is the first and the only Asian country that is planting transgenic crops commercially on a large scale. Six transgenic crops granted

Marzukhi Hashim, Vilasini Pillai, Umi K. Abu Bakar, Habibuddin Hashim, and Hassan Mat Daud are affiliated with the Malaysian Agricultural Research and Development Institute, in Serdang, Selangor, Malaysia. Mohamad Osman and Ruslan Abdullah are affiliated with the Universiti Kebangsaan Malaysia, in Bangi, Selangor, Malaysia.

licenses for commercialization in 1999 were dominated by Bt cotton from the Chinese Academy of Agricultural Science and Monsanto, transgenic tomato from Beijing University and CCAU, and transgenic petunia and sweet pepper from Beijing University. Of these six crops, Bt cotton was planted on more than 350,000 hectares during 1999 and 2000 [1].

Intensive and advanced biotechnological research on local crops is being carried out in 5 of the 10 ASEAN countries—Singapore, Malaysia, Thailand, the Philippines, and Indonesia—while the other 5 are still at earlier stages of biotechnology.

Several ASEAN countries, for example, Thailand and the Philippines, have field-tested GMOs. Thailand is currently participating in the International Rice Genome Consortium project to sequence chromosome 9 of the Nipponbrae rice genome and is field testing Bt cotton and Bt corn and the Flavr Savr tomato [2]. Indonesia is reported to have commercial field release for Bt cotton in Sulawesi. Malaysia at the moment has not approved any field trial or commercial transgenic crops in the field; however, field trials of papaya ring spot virus–resistant papaya and tungro-resistant rice are expected in the near future, after enough seeds have been acquired and approval by the Genetic Modification Advisory Committee has been secured.

Malaysian agriculture and biotechnology

Agriculture

Located in the tropics, Malaysia, with a population of more than 23 million, consists of two major land masses straddling the South China Sea: Peninsular Malaysia and East Malaysia (Sabah and Sarawak on the island of Borneo). The country has an area of 330,000 km^2, with 138,000 km^2 in Peninsular Malaysia and the remainder in Sabah and Sarawak.

Malaysia covers a total of 33.06 million hectares of land, of which 7.15 million, 3.15 million, and 4.45 million hectares are estimated to be suitable for agriculture in Peninsular Malaysia, Sabah, and Sarawak, respectively. The sector is dominated by plantation crops, of which oil palm (2.0 million hectares) is the major crop, followed by rubber (1.2 million hectares) and cocoa ($<$ 0.4 million hectares). Of the food crops, the area grown in rice is the largest, followed by fruits and vegetables.

Although agriculture was traditionally the most dominant sector in Malaysia, it has been supplanted by the rapidly expanding industrial and service sectors. Agriculture contributed 29% to the national gross domestic product in 1970, but it declined to 14.8% in 1994 and is estimated to have dropped to 13% in 2000.

Research on biotechnology

Intensified research on priority areas (IRPA) programs

Under the competitive IRPA program managed and coordinated by the Ministry of Science, Technology and the Environment, research institutions and universities undertake research on biotechnology in many scientific areas. Research is carried out as experimental, applied, or prioritized research or as strategic research projects. Top-down IRPA projects (both prioritized research and strategic research) are multi-institutional projects accorded very high priority because of their national importance.

Research on agricultural commodities is carried out by various research institutions: research on oil palm by the Malaysian Palm Oil Board; rubber by the Malaysian Rubber Board; cocoa by the Malaysian Cocoa Board; and rice, fruits, vegetables, and other crops by the Malaysian Agricultural Research and Development Institute. Many of these projects are complemented by research carried out by universities and other institutions.

As an integral program to enhance the productivity of these important crops, research on biotechnology has been given emphasis in such areas as genetic engineering for plant improvement, molecular marker technology, plant cell culture/bioreactor systems, and in vitro technology.

Research priorities

Although it is extremely difficult to develop research priorities, owing to limited resources and institutional crop mandated assignments, the following crops/plants with target traits have been recommended (quoted here from the Seventh Malaysia Plan) [3]:

» Oil palm: oil quality, secondary plant products
» Rubber: disease resistance, yield, production of high-value products
» Rice: disease resistance, yield
» Ornamentals: senescence, flower color, disease resistance
» Fruits: shelf-life, disease resistance, fruit quality
» Cocoa: insect and disease resistance, butter content, and cocoa flavor
» Forest species and medicinal plants: nutraceutical and pharmaceutical products

In the development of transgenic crops and genes of interest (see table 1) in the country, intensified research has been carried out in the following crops:

» Oil palm (Malaysian Palm Oil Board, Universiti Kebangsaan Malaysia)
» Rubber (Malaysian Rubber Board)
» Rice (Malaysian Agricultural Research and Development Institute [MARDI])
» Papaya (MARDI)
» Orchid (MARDI, Universiti Putra Malaysia)

TABLE 1. Current status of transgenic plant development in Malaysia

Crop and objectives	Gene of interest	Status
	Rice (MARDI)	
Resistance to rice tungro spherical virus (RTSV)	Coat protein and polymerase genes of RTSV	Stable (Taipei 309) transgenic lines, T147-3 and T147-4, carrying truncated and full-length polymerase genes, respectively [4]
Resistance to rice tungro bacilliform virus (RTBV)	Coat protein and polymerase of RTBV [5]	Transformation and screening ongoing
Resistance to sheath blight disease (Rhizoctonia oryzae)	Chitinase gene[a] [6]	Transformation and screening ongoing
Tolerance to herbicides	BAR gene [7]	Transformation and screening ongoing
Resistance to insects	Bt gene[a]; cowpea trypsin inhibitor (CPTi)[a]	Transformation and screening ongoing
	Papaya (MARDI)	
Resistance to papaya ring spot virus (PRSV)	Coat protein of local isolates of PRSV [8]	Transgenic plants obtained, in tissue culture; ready for greenhouse screening[b]
Improved shelf-life	ACC oxidase gene (antisense) [9]	Transgenic plants went for a field trial in March 2002[b]
	ACC synthase gene	Transformation ongoing [9]
	Oil palm (MPOB and UKM)	
Oil quality improvement	Stearoyl-ACP desaturase and β-keto-acyl synthase 1	Transformation system developed [10–12]
Herbicide tolerance		Transformation system developed [13]
Insect resistance	CPTi[a]; Bt gene[a] [14-16]	Transgenic plants obtained (4½ yr old), in planthouse; ready for screening [1, 14–16]
Fungal resistance (Ganoderma)	Chitinase[a] [14–16]; RIP[a]	Transgenic plants obtained (3 yr old), in planthouse; undergoing screening [15, 16]
	Rubber (MRB)	
Specific proteins (e.g., pharmaceuticals)	—	Transformation system developed [17, 18]
	Orchid (MARDI and UPM)	
Resistance traits	—	—
Improved flower color	Chalcone synthase (CHS)	Gene construct prepared [19]
Improved shelf-life	Flavanone-3-hydroxylase (F3H)	
	ACC oxidase [20]	Transformation ongoing

a. R. Ruslan, personal communication, 2002.
b. Potential breakthrough and applications for field trials are subjected to approval by the Genetic Modification Advisory Committee.
Abbreviations: MARDI, Malaysian Agricultural Research and Development Institute; MPOB, Malaysian Palm Oil Board; UKM, Universiti Kebangsaan Malaysia; MRB, Malaysian Rubber Board; UPM, Universiti Kebangsaan Malaysia.

The National Biotechnology Directorate, the Plant Biotechnology Cooperative Centre, and the National Biotechnology and Bioinformatics Network

An important event in the development of biotechnology in Malaysia was the establishment in 1995 of the National Biotechnology Directorate (NBD), a division of the Malaysian Ministry of Science, Technology and the Environment. The mission of NBD is to spearhead the development of biotechnology through research and related activities directed at the commercialization of biotechnology and to establish Malaysia as the leading center for the biotechnology industry.

To facilitate and enhance biotechnology efforts, NBD established seven specialized centers known as Biotechnology Cooperative Centres (BCCs): the Plant

BCC, Animal BCC, Food BCC, Biopharmacy BCC, Environmental/Industrial BCC, Molecular Biology BCC, and Medical Biotechnology BCC.

NBD also set up the National Biotechnology and Bioinformatics Network to develop an efficient biotechnology community for bioinformatics and biotechnology applications using the latest computer technology. The network uses a wide-area network to link BCCs and other biotechnology research centers nationwide, enabling biotechnology researchers to share information pertaining to their research and otherwise promoting interactions and communications among the individual research centers.

Research and development on transgenic plants

Crops being researched

The crops that are being intensively researched include oil palm by the Malaysian Palm Oil Board as the anchor institution, rubber by the Malaysian Rubber Board, rice and papaya by MARDI, and orchids by MARDI and the Universiti Putra Malaysia.

Although some research projects, such as those on rice and papaya, have almost completed transgenic development, there is as yet no transgenic crop candidate that is about to go into field trials. However, in anticipation of such an eventuality, steps have already been taken to familiarize scientists with applications and protocols for field testing transgenic crops (e.g., papaya), biosafety regulations, and biosafety concerns relating to transgenic crops and products* [21]. As a significant development for research, a transgenic greenhouse was constructed in MARDI early last year, and it is expected to be ready for use by this year. More funding was approved in 2001 for another transgenic testing greenhouse.

Potential breakthroughs

Of the five crops that are in different stages of transgenic development, two, papaya and rice, have reached an advanced stage of transgenic development from which breakthroughs could be possible in the near future. These two crops are followed closely by oil palm and orchids.

Papaya. At the beginning of the papaya research, researchers successfully cloned the ripening-related 1-amino-1-cyclopropane carboxylic acid (ACC) oxidase gene from *Eksotika papaya* and made an antisense gene cassette for plant transformation [9, 22]. They also developed an efficient transformation system for *E. papaya* using particle bombardment and successfully produced transformed papaya lines containing the antisense ACC oxidase gene [23, 24].

Transformation of papaya with the antisense ACC oxidase gene construct, *pCaPACO1AS*, was by the biolistic method. Molecular and biochemical characterizations were performed on the six most mature plants kept in the greenhouse.

Because papaya cannot fruit in the greenhouse, a contained field trial has to be conducted for fruit-ripening analysis. In the contained field trial, transformed plants will be grown and maintained under a netted structure. Only the roots will be in direct contact with the environment, whereas the other parts of the plants, including the pollen, will be contained. The trial will be for a "proof of concept." Nontransformed lines will be grown in border rows as controls.

The field trial application will be submitted to the Malaysian Genetic Modification Advisory Committee for approval soon after the data on gene copy number have been obtained. Funding has just been received from the International Service for the Acquisition of Agri-biotech Applications for the construction of a net house. Construction is expected to be completed by early 2002. The location will be in Mardi Serdang, an area that is free of papaya ring spot virus.*

Protection against papaya ring spot virus by coat-protein-mediated resistance has been shown to be strain specific [25]. To overcome this, a gene from a local isolate of the virus was isolated, and the construct was deployed in papaya transformation [8, 26]. Resistance tests will be done initially on segregating R_1 progeny and confirmed on the homozygous R_2 population.**

Rice. At present, the transgenic rice plant that confers pathogen-derived resistance to rice tungro spherical virus via polymerase genes has been advanced for several generations and is ready to be field tested [4]. However, this transgenic plant has been developed on Taipei 309, a japonica type that may not be agronomically suitable in the Malaysian environment. An attempt has been made to cross this transgenic japonica line with local indica lines. Progenies of this cross have

* Chan YK. Case study of proposed field releases of a virus resistant transgenic papaya in ASEAN region. Presented at the ASEAN Regional Workshop on Biosafety of Genetically Modified Organisms (GMOs), Kuala Lumpur, April 24–26, 2000.

* Abu Bakar UK, Vilasini P, Pauziah M, Lam PF, Chan YK, Hassan MD. Molecular and biochemical characterisations of *Eksotika papaya* plants transformed with antisense ACC oxidase gene. Presented at the Papaya Biotechnology Network of SEAsia Coordination Meeting, Hanoi, Vietnam, October 25–26, 2001.

** Vilasini P, Hassan MD, Flasinski S, Kaniewski WK, Ong CA, Chan YK. Presented at the Papaya Biotechnology Network of SEAsia Coordination Meeting, Hanoi, Vietnam, October 25–26, 2001.

the transgene and indicate that the transgene is inherited in a Mendelian ratio [27]. However, individuals with the transgene, which was positively confirmed by polymerase chain reaction, failed to express their resistance after being challenged with the virus and tested by enzyme-linked immunosorbent assay.

Work is now being carried out to produce transgenic rice resistant to rice tungro bacilliform virus, another form of the virus that is more destructive than the spherical virus. Both the coat protein (C. A. Ong, personal communication, 2002) and the protease genes [28] have been successfully cloned.

Oil palm, orchids, and rubber. Most research work on the transgenic development of crops other than rice and papaya is in the early developmental stages.

Transgenic palm oil plants with different model transgenes have been obtained [13, 14], namely, those with resistance to hygromycin, β-glucuronidase activity, and herbicide (Basta) resistance. Molecular analysis and physical screening confirmed the expression of the transgenes in the regenerated plants, obtained by both *Agrobacterium*-mediated and direct DNA transfers through particle delivery systems. Recently, Rashdan and Abdullah [16] and Abdullah et al. [29] reported significant progress with *Agrobacterium*-mediated transformation of chitinase into oil palm, and transgenic and chimeric oil palm plants carrying the cowpea trypsin inhibitor gene were found to be resistant to bagworm larvae.

Genes of the fatty acid biosynthetic pathway of the oil palm have been cloned, characterized, and used for gene construction. Vectors have been constructed with inserts of stearoyl-ACP (acyl carrier protein) desaturase and β-keto-acyl synthase 1 genes for oil palm transformation [30], and the isolation and characterization of cDNA clones encoding for oil palm thioesterase have been reported [10].

To date, orchid transformants (var. *Dendrobium*) with the objective of prolonged shelf life have been recovered in MARDI, but these transformants will need 1½ to 2 more years to flower to permit shelf-life analysis. Work by Universiti Putra Malaysia to effect color change in var. *Dendrobium* is still ongoing (U. K. Abu Bakar, personal communication, 2002).

For rubber, Arokiaraj et al. [17, 18] have established a protocol for gene transfer and plant regeneration technology using genes resistant to β-glucuronidase activity and kanamycin. One primary goal is to produce commercially valuable proteins by transgenic rubber trees. Taking advantage of the fact that the rubber tree yields copious latex when tapped, transgenic trees would become natural living factories for the production of foreign protein such as pharmaceuticals and proteins used in personal care products. By using the transformation systems that have been developed, it is hoped that such protocols can be used to incorporate any gene of interest into rubber.

Research and development problems encountered in transgenic crops

Based on our experience, the following problems have been encountered in the course of developing transgenic crop plants, and these need to be addressed.

Research

Regeneration problems, specifically for indica rices, papaya, and oil palm

Failure to obtain sufficient numbers of successful transgenic plants occurs because of the genotype specificity of the protocol, especially for rice and papaya [31]. Some local indica rice varieties (e.g., MR 81) could be successfully transformed with foreign genes and regenerated [7, 32], whereas efforts with other MR varieties have encountered difficulties in regeneration to produce enough R_0 individuals for selection and screening. This problem has been highlighted elsewhere [33].

Gene silencing and expression

The results from several research activities, for example, in rice, indicated the presence of transgenes and confirmed their Mendelian inheritance; however, these transgenic plants failed to express the specific target trait(s). Perhaps this is related to the problem of gene silencing and expression.

Resistance traits conferred by location-specific pathogens (biotypes, pathotypes, etc.)

In the development of resistance traits in transgenic plants, there are instances in which location-specific pathogens become very relevant, such as for papaya, because readily available foreign genes for resistance may not be effective.

Availability of construct's components

For various reasons, researchers sometimes confront problems and delays in procuring components of specific construct(s) for their work.

Transparency in biotechnology research techniques

As in most research work, researchers are not always willing to disclose and share their techniques with other colleagues, and these techniques may be very useful for transgenic development. This is understandable, since they may not want to lose the rights to patent their new findings. Although this may not be a critical problem, it can slow down research and increase "reinventing of the wheel" work.

Infrastructure

Insufficient number of scientists and inadequate research support

In general, there is a lack of a critical mass of scientists and research support needed to develop transgenic crops in Malaysia. To make matters worse, researchers in research and development institutions, such as the Malaysian Palm Oil Board, the Malaysian Rubber Board, and MARDI, and those in universities are confined to working on mandated crops. This limits the pool of expertise available to work on problems outside of their respective institutional mandated crops. There is also a need to train more scientists to provide more research support [21].

Limited knowledge of the molecular and plant biotechnology of local crops

With the exception of rice, there is little plant biotechnology research conducted outside the country on local crops important to the Malaysian economy. This leads to limited availability of construct elements (e.g., genes, promoters, enhancers, terminators, and other DNA sequences) and of scientific literature on crops such as oil palm and rubber [21].

Research and development funding for transgenic crops

Since the creation of the NBD in 1995, the amount of funding for research on biotechnology, including transgenics, has increased significantly. In 1996, there was a total research and development expenditure of US$144.5 million in 15 fields of research, and of this, US$32.3 million, or 22.4%, was for the biological and agricultural sciences. In the five-year-plan period 1996–2000, more than US$13.0 million was allocated for biotechnology (US$1 is equivalent to RM [ringgit Malaysia] 3.8).

Biosafety

The responsibility for regulating GMOs in Malaysia lies in the Ministry of Science, Technology and the Environment, the National Biodiversity Committee, the Genetic Modification Advisory Committee, and the Institutional Biosafety Committee.

Cartagena protocol on biosafety and the biosafety bill

After the derailment of the Cartagena Protocol on Biosafety in 1999, many countries, particularly developing countries, including Malaysia, began tightening their controls and undertook policy, legislative, and administrative measures to regulate the transboundary movement, handling, and use of GMOs and to minimize their adverse effects on the environment and on human health.

Malaysia, a signatory to the protocol, has international obligations on biosafety issues with regard to laboratory tests, field trials, and commercialization. As one of the world's most biodiverse countries, Malaysia is cognizant of the fact that GMOs may have adverse impacts on the conservation and sustainable use of biodiversity.

Together with many other countries, Malaysia signed the Cartagena Protocol on Biosafety at the Fifth Meeting of the Conference of Parties to the Convention in Nairobi, Kenya. After a number of national consultative discussions in 2001, Malaysia finalized a draft law on biosafety (referred to as the Biosafety Bill). The Biosafety Bill regulates and manages the importation, deliberate release into the environment, market approval, and contained use of GMOs and products thereof. It is expected to be passed by the Parliament in 2002.

Genetic Modification Advisory Committee (GMAC)

The Ministry of Science, Technology and the Environment established the Genetic Modification Advisory Committee (GMAC) with the objectives of ensuring that any risks associated with genetic modifications and GMOs arising from such activities be identified and safely managed, and of advising the government about matters of genetic modification. GMAC is also responsible for the assessment of proposals on the planned release of GMOs into the environment. Malaysia has been proactive in its regulatory activities: GMAC formulated National Guidelines for the Release of Genetically Modified Organisms (GMOs) into the Environment, which were officially issued by the Minister of Science, Technology and the Environment in January 1997 [34].

To date, only one application for the release of a GMO has been received by GMAC. This was for the importation into Malaysia of the glyphosate-resistant Roundup Ready soybean from Monsanto for food and feed. Notwithstanding that the application was for food and feed and not for planting, a cursory assessment of the likely impact of the GMO on the environment was nonetheless carried out. Since Malaysia is neither the center of origin nor the center of diversity for soybeans, coupled with the fact that soybeans are not cultivated widely in the country, the likelihood that it would cause harm to the environment was considered to be very low [33].

National Guidelines for the Release of Genetically Modified Organisms (GMOs) into the Environment

The guidelines were issued in 1997 to cover all GMOs (including plants, animals, microbes, etc.) at all stages of research and development, use, handling, transboundary movement, release, and placing in the market of GMOs and products containing GMOs, and to address biosafety issues in biotechnology such as risk assessment, risk management, and monitoring. The guidelines were based on those of the United Nations Environment Programme. According to the guidelines, risk assessment is conducted based on the precautionary principle and on a case-by-case basis, and considers all related social, religious, and ethical issues. The guidelines were developed to promote biotechnology and not to hamper it, and they are intended to be dynamic and flexible. To ensure compliance, many relevant elements have been incorporated into the biosafety bill.

Institutional Biosafety Committee

The establishment of a biosafety committee within an institution is vital in providing a focal point for the overall monitoring of genetic modifications and the execution of the national guidelines. Committee members are not involved in the review or approval of their own research projects or of commercial applications.

Public awareness and acceptance of transgenic crops or products

There has been a great deal of controversy about the introduction of genetically modified crops and foods. Many people the world over are concerned that genetically modified crops could have harmful effects on human health and cause irreversible damage to the environment.

Transgenic soybean has been available in Malaysia since GMAC approved its importation in 1997, and since then there have been calls from consumers to ban its import. It has been decided, however, that there will be no moratorium on its import until findings to the contrary are made with regard to its safety for human health.

There has been a significant effort to increase public awareness of GMOs via television and radio programs, newspapers, public forums, discussion groups, task forces, and committees in which scientists, nongovernmental organizations, consumers, and others participate. In April 2000, the Ministry of Science, Technology and the Environment organized the ASEAN Regional Workshop on the Biosafety of Genetically Modified Organisms, in Kuala Lumpur, with the participation of ASEAN delegates.

In view of concerns raised about transgenic crops—concerns that have exceeded, in scope, actual experience with their use—and criticisms of the regulatory process and controls, it is pertinent that steps be taken to clarify the regulatory process and controls. All transgenic crops carry risks and benefits to a greater or lesser extent. Whether consumers accept or reject transgenic crops or products very much depends on their confidence in risk assessment and risk management and in the regulatory process itself.

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Opportunities for nutritionally enhanced maize and wheat varieties to combat protein and micronutrient malnutrition

David Hoisington

Abstract

Naturally occurring variation detected in the germplasm of maize and wheat, two of the top three cereal crops in the world, provides options for incorporating higher levels of iron, zinc, and β-carotene into these grains. In addition, quality protein maize (QPM) has been developed from naturally occurring variation; its seed contains enhanced levels of lysine and tryptophan, two essential amino acids lacking in cereals. The International Maize and Wheat Improvement Center, along with its many partners, has identified several maize and wheat varieties with 25% to 30% higher grain iron and zinc concentrations. Wild relatives of wheat have been found to contain some of the highest iron and zinc concentrations in the grains. Although these accessions are often low yielding and have poor grain quality, backcrossing to bread wheat could result in highly nutritious cultivars. Options are now available for conventional and biotechnology-assisted improvement of the nutritional content of maize and wheat germplasm.

Key words: Nutritionally enhanced, maize, wheat, micronutrient malnutrition

Maize and wheat are two of the top three cereal crops in the world. Maize is the preferred staple of more than 1.2 billion consumers in sub-Saharan Africa and Latin America, where 30% to 50% of the population, particularly the poor and women and children, are affected by malnutrition. In Africa alone, many poor people subsist on a maize-based diet low in iron and zinc [1]. As an example, 30% of pregnant and lactating women in Zimbabwe are thought to be iron deficient [2]. Wheat is an important staple in the low- to lower-middle-income countries, where the annual per capita consumption ranges from 40 kg to more than 200 kg. Wheat contributes significantly to the caloric and protein requirements of consumers in these countries.

The International Maize and Wheat Improvement Center (CIMMYT), based in Mexico, has conducted research on nutrition-related traits for more than two decades and has arrived at several options for addressing nutritional deficiencies through maize and wheat improvement. In collaboration with governments and national agricultural research institutions in several countries (such as Brazil, China, El Salvador, Ethiopia, Ghana, Guatemala, Malawi, Mexico, Mozambique, and Uganda), CIMMYT has been promoting the use of quality protein maize (QPM). QPM is visually indistinguishable from normal maize, but it is of superior nutritional value because the levels of lysine and tryptophan are effectively doubled. Varieties of QPM have been released in several countries. It is estimated that they are currently grown on almost 1 million hectares, and the area is increasing. Apart from providing better-balanced protein, lysine is a known promoter of iron and zinc absorption in humans. Even with an unchanged iron or zinc concentration, iron and zinc uptake in humans consuming QPM is expected to increase.

Few if any studies have investigated whether a more balanced amino acid profile is feasible in wheat, but it should be. One difficulty may lie in the fact that wheat is usually processed into breads or other baked products. It is known that flour quality is greatly affected by changes in the protein composition of the grain. Thus, amino acid modifications in wheat would need to be carefully studied for their effect on grain quality.

More than one-third of the world's population is iron deficient, and some 1.2 billion people are anemic. The problem for women and children is more acute because of their greater physiological need for iron. Zinc deficiency has received less attention than other micronutrient deficiencies, but zinc deficiency is assumed to be widespread. Since the early 1990s, CIMMYT has been evaluating maize and wheat accessions and varieties for

The author is affiliated with the International Maize and Wheat Improvement Center (CIMMYT) in Mexico, where he is the director of CIMMYT's Applied Biotechnology Center and Bioinformatics.

genetic variability of grain iron and zinc concentration. Experimental maize hybrids and varieties with 25% to 30% higher grain iron and zinc concentrations than are found in currently grown cultivars have been identified. Similar studies in wheat have indicated that iron and zinc concentrations in cultivated varieties can differ by 30% to 40%.

Some of the best sources of high iron and zinc concentrations in wheat are the wild relatives: *Triticum dicoccon, T. boeoticum*, and *Aegilops tauschi*. These are often low yielding, with poor grain quality, but through backcrossing to bread wheat, good cultivars can be obtained. Preliminary feeding studies carried out using rats have indicated a positive correlation between higher iron in the grain and higher levels of bioavailable iron in the diets fed to the rats. Further studies are under way to develop appropriate genetic populations for genomic studies of high iron and zinc concentrations in maize and wheat.

The World Health Organization reported in 1994 that 3.2 million preschool-age children have eye damage as the result of vitamin A deficiency and that another 228 million are subclinically affected at a severe or moderate level. CIMMYT and its sister institute, the International Institute of Tropical Agriculture, are exploring avenues for overcoming vitamin A deficiency resulting from maize-based diets. Yellow maize contains naturally occurring and significant amounts of provitamin A carotenoids (e.g., β-carotene) that can be converted to vitamin A in humans. Unfortunately, most consumers in sub-Saharan Africa and a considerable proportion in Latin America reject yellow maize for cultural and historic reasons. These consumer preferences might be overcome by promoting the consumption of high-β-carotene (yellow) maize as fresh, boiled, or roasted maize, or by developing high-β-carotene maize with a distinctive yellow grain color. CIMMYT has found considerable amounts of carotenoids in landraces of maize with sun-red grain color. There are plans to introduce these grain colors, along with higher β-carotene levels, into local varieties and to assess consumer preferences for elite, tasty, and more nutritious maize. A higher-technology solution may be via the genetic engineering of β-carotene production only in the embryo. This should lead to a less yellow-colored grain, which may be more acceptable. Issues surrounding the use of genetic engineering and grain processing (the grain is often degermed for storage) will need to be addressed.

There are already high-yielding varieties of both bread and durum wheat that are yellow in color, although the levels of provitamin A carotenoids are still being determined. Only a small fraction of the wheat genetic resources available have been screened appropriately for the level of carotenoids. It is possible that significant variation does exist and could be used to increase the level of β-carotene in elite varieties. One interesting observation is that wheat does produce detectable levels of β-carotene [3]. These levels are detected early in grain development but are absent in the fully developed grain. Thus, it appears that wheat possesses all of the necessary enzymes for β-carotene production, but that it processes β-carotene to other products in the carotenoid pathway (e.g., luteins). Given that all of the major enzymes in the carotenoid pathway are known and have been cloned [4], it should be feasible to block the pathway immediately after β-carotene production and thus elevate the levels of β-carotene in the grain. Other enzymatic steps may also need to be modified to produce the highest and most stable levels of β-carotene while not affecting other characteristics of the grain.

Enhanced nutritional quality of staple grains is of high priority. The naturally occurring variation already detected in maize and wheat germplasm provides options for incorporating higher levels of iron, zinc, provitamin A, and better-balanced protein into the grain of these important cereals. Genomic approaches, including genetic engineering, offer novel ways to further enhance these traits, especially those involving micronutrients such as iron, zinc, and β-carotene. Providing nutritionally enhanced cereals to resource-poor populations in developing countries offers an excellent opportunity to combat many of the devastating nutritional-deficit diseases affecting the world.

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Biotechnology-derived nutritious foods for developing countries: Needs, opportunities, and barriers: Discussion Summary

Abstract

Improvements in diet diversification and quality can be facilitated by greater cooperation between the agricultural and the nutrition communities, according to an expert panel that met in early 2002. Encouraged to think innovatively, the panelists agreed that modern technology offers the potential to increase the amount and nutritional content of the food supply in developing countries, especially if the enhancements are made to the highest-yielding indigenous staple crops and if a total food-systems approach is taken. All types of interventions should be evaluated for their cost-effectiveness in preventing nutritional deficiencies in the developing world and for their sustainability.

Key words: Nutrition, biotechnology, biofortification, diversity

A distinguished group of international experts met in Cancun, Mexico, on January 15–17, 2002, to address nutritional deficiencies in developing countries through improvements in diet diversification and quality. These improvements, they agreed, would be facilitated by greater cooperation between the agriculture and nutrition communities. Modern biotechnology was explored as a potentially significant method to achieve this goal in the context of other approaches, such as traditional plant breeding, dietary supplementation, and fortification of food staples.

The objectives of the workshop were to identify

- nutritional needs that could be effectively met through biotechnology-derived foods;
- opportunities and areas in which the applications of the techniques of biotechnology could benefit nutritional needs;
- products under development that would meet these needs;
- opportunities for and barriers to the development of such products and their acceptance; and
- next steps: research, technology transfer, information dissemination, and additional workshop discussions and expert panel deliberations.

Because each developing country or region presents particular challenges, participants encouraged the development of innovative solutions to unique problems. Infrastructures, such as research facilities, regulatory agencies, and biosafety procedures, need to be put in place in many areas even before much-needed funding can be spent efficiently. Increased dialogue among networks of the nutrition and the agricultural communities is needed for capacity building in developing nations to successfully implement these and other strategies.

The group noted that the array of tools provided by modern biotechnology offers the potential to increase the amount and nutritional content of the food supply in developing countries. The group also noted that nutritional enhancements would probably be most effective if they were made in locally grown and familiar crops. The greatest potential for modern biotechnology to address real problems may lie in using a total food-systems approach that focuses on enhancing indigenous crops in developing regions, coupled with the use of the highest-yielding staple crops to boost both food security and nutritional quality.

All types of interventions, participants agreed, need to be evaluated for their cost-effectiveness in preventing nutritional deficiencies in the developing world, and their costs and benefits should be considered broadly. Assessment should include sustainability and the likelihood that the different strategies will promote, support, and improve dietary diversity.

Nutrition issues facing developing countries

The nutritional status of populations of the developing world is affected by several factors, including population density and rate of growth, the ability of the population to grow or buy enough staples for its own use, and economies of scale in agricultural research that decrease the diversity of the food supply. Thus, there is often tremendous variability in nutritional status among countries within a region.

The global population of 6.1 billion in 2000 is expected to grow by 800 million per decade to at least 8.2 billion by 2030, with just six countries accounting for most of the growth. Today 800 million people in the world are hungry, 400 million suffer from vitamin A deficiency, and 3 million children die from this deficiency each year. Two billion people suffer from iron deficiency, and many more have inadequate or unbalanced intakes of protein, carbohydrates, lysine, iron, iodine, niacin, and zinc. The prevalence of anemia in South Central Asia runs as high as 75%. Low birthweight and the resultant stunting of growth affect nearly 30% of children in developing countries (165 million children). Undernutrition is one of the most significant factors facing the developing world, but some regions are also experiencing diet-related chronic diseases of overnutrition, such as diabetes, obesity, hypertension, and cardiovascular disease, that are related to the consumption of excess energy and other dietary imbalances.

Twenty percent of the world's people are food insecure: they rely on their own or just a few other resources for their food. Only 20% of the world's people are affluent enough to have access to nutritious diets. Lack of dietary diversity is common in many developing nations. In one extreme example, Bolivia relies primarily on 10 different foods for sustenance, down from 64 over the past few decades. This lack of diversity and overdependence on a few staple crops results in a wide variety of micronutrient deficiencies, the so-called multinutrient deficiency syndrome, that is likely to be a harbinger of reduced physical productivity, decreased cognitive ability, higher rates of infant mortality, and other problems that plague undernourished populations. Food-based approaches using plant breeding and/or biotechnology to address nutrient deficiencies should be implemented in a manner that does not exacerbate the malnutrition problems associated with a declining diversity in the food supply.

Another factor affecting nutritional status relates to a population's ability to devote resources to sustain the health and welfare of its people. For example, 70% of the world's senior citizens live in developing nations. Many of these individuals, particularly in Africa, are facing even more difficult challenges in caring for AIDS victims and their orphans while sustaining their own lives. Time spent tending to the aged, the sick, and orphaned children competes with time needed to obtain and prepare food and to foster a nurturing environment.

Challenges to improving nutrition and food security

Nutrition and agricultural experts from developing nations who participated in the workshop cited a number of factors that prevent their populations from improving their nutritional status. Among them are deteriorating socioeconomic status; the persistence of widespread poverty; high disease burden; reduced public investment in nutrition and agricultural programs and related research and development; lack of education, which is a factor in both under- and overnutrition; limited technical capacity to provide solutions; diminishing land and water resources; political instability and/or lack of political will to allocate resources; and costs associated with yearly farm inputs, such as seed, fertilizer, and pesticides. Even where plans to address nutrition and food security issues have been developed, often there are not adequate resources to implement the plans.

Examining potential solutions

The participants were asked to consider current and future approaches best suited to meet priority nutritional needs in developing countries. They compared and contrasted approaches that included supplementation, fortification, dietary diversification, traditional plant breeding, and modern biotechnology based on the following criteria: benefits, cost, proven efficacy, difficulty of implementation, long-term and short-term impacts, and reachable population. Each of these approaches was seen as having strengths and weaknesses relative to specific nutritional problems and the biologic, economic, and behavioral dimensions of the problems. These approaches need to be seen as a portfolio of strategies rather than as competing approaches.

A consensus emerged that in each developing country, it is necessary to examine alternatives comprehensively—from a total food-systems approach—rather than focusing on certain micronutrients or on single crop-oriented strategies. Supplementation was seen as a short-term approach that is already being used in a number of countries with limited success. Concerns about cost and ability to reach enough people place limits on the potential for the sustainable success of traditional biomedical, i.e., supplementation, approaches. More experience is available on the sustainability of fortification practices, but this option also should be evaluated from a total health-systems approach.

Education is needed in all areas to encourage a total dietary approach that maximizes the consumption of fruits, vegetables, cereals, and legumes using the best available crop varieties. Diversifying plant and animal food sources was also cited as a critical component of any potential solution. Although improving dietary diversity was seen as the most desirable strategy for improving the nutritional status of populations, the experts acknowledged that this may be a difficult strategy to implement over the short term, because current economic structures favor the production of a few crops and because of the lack of attention given to maintaining accessibility to diverse diets.

Other approaches include biofortification, a term coined by the Consultative Group on International Agricultural Research (CGIAR), that covers the use of both traditional breeding and modern biotechnology to increase the levels of nutrients in crop foods, education, and social marketing. Although biofortification is yet to be implemented and carefully evaluated in the field, preliminary evidence suggests that it should be exceptionally cost-effective. The acceptability to farmers and consumers of biofortification requires evaluation, especially when consumer characteristics (e.g., color) are altered.

As populations increase and as other pressures on the demand for food drive up the prices of mineral- and vitamin-dense nonstaple foods, biofortification strategies should seek to redress in part the greater dietary dependence by the poor on a few staple crops. At the same time, more productive varieties of food staples have been developed through investment in agricultural research in developing countries, which has lowered the prices of cereals and roots and tubers and has ensured better food security in terms of energy intakes.

Creative approaches might involve not only enriching nutrients in plants but also making a more diverse array of plants able to thrive in a particular area, reducing postharvest losses, especially for tropical fruits, or even enabling lifestyle changes that reduce the time needed to tend fields that could be better spent caring for people in need. Likewise, "orphan crops," i.e., crops of nutritional importance to local areas or regions, can help diversify the diet and avoid overdependence on a few staple crops. Although these strategies can serve a critical need by promoting more diverse diets, a careful evaluation of costs and benefits is yet to be undertaken.

Investment in new technologies is essential to improving nutritional status, but other factors are also essential. These include the promotion of an effective dialogue among scientists, farmers, consumers, and policy makers; within-country capacity building in research and the creation of enabling regulatory frameworks; and the support of key decision makers. With these capabilities in place, agriculture and nutrition can form new partnerships to improve public health. The participants called for a new paradigm in linking the agriculture and nutrition sectors, as well as the environmental sector, in both research and community development. Research will determine which agricultural practices—conventional breeding or biotechnological methods—offer the best approaches for achieving specific nutritional and environmental goals. Strong community-level communication among all of the interested parties is essential to translating research findings into practice. In addition, there must be political and financial commitment at the local level to foster an environment in which enabling policies and regulatory structures can be developed.

Focus on biotechnology

The participants were asked to focus specifically on the types of nutritional issues that might benefit from the use of modern biotechnology. In approaching this question, the participants noted that discussions of biotechnology are often narrowly focused on genetic engineering of agricultural products rather than on the full range of innovations introduced by biotechnology. This array of tools provides flexibility and new approaches for improving crops. These tools include the ability to transfer genes from nonplant sources into crops to provide desirable traits not available from plant sources; more efficient and effective breeding by using markers to confirm gene transfer; the use of tissue culture to produce disease-free cultivars and cultivars with improved traits; improvements in disease diagnosis to manage existing diseases or to reduce the risk of disease in livestock and plants; and the production, testing, and delivery of vaccines. The advantages of using biotechnology will depend on the specific trait and crop of interest.

The participants stressed that modern biotechnology should be based within a systems context and should be used where biotechnology offers the best approach or application. Biotechnology must also gain greater public acceptance through information sharing and education. Achieving greater acceptance will require information sharing and education of industry, government, and the public. Although the participants acknowledged that foods developed by modern biotechnology can be as safe as their traditional counterparts, representatives from a number of developing nations stressed the need to address the low level of understanding of the needs of the developing world and the diverse misperceptions of industry, governments, and the public regarding the nature and basis for acceptability of bioengineered foods. Some were of the view that biotechnology offers great hope for improving nutrition but expressed concern about how it can be implemented in the current environment. One strategy for moving beyond the status quo is to increase public-sector support for research and development of crops of interest to regional consumers and producers.

Some participants noted that we have the knowledge to make a major difference in the lives of many less fortunate people in developing countries. However, knowledge is not enough; the challenge is to empower and build capacity in these populations to successfully advocate for solutions that meet their needs. As their leaders understand the dimension of their food-security and nutrition problems, they need access to the full portfolio of strategies, including new technologies such as modern biotechnology, to tackle these problems.

Barriers to the implementation of biotechnology solutions include a lack of tools for evaluating the safety of transgenic foods and the effects of transgenic crops on the environment before public concerns can be satisfied; the lack of a track record for transgenic foods and the concomitant fear of the unknown, which also occurred for some conventionally bred crops; limitations in the types of crops developed to date; high startup costs; lack of public investment; lack of research funds beyond those for major crops; lack of incentives for farmers to adopt transgenic crops and the private sector to invest in them; limited access to the new technology owing to intellectual property rights; inadequate local regulations; and lack of awareness of the potential of biotechnology.

In the 1960s and 1970s, the Green Revolution succeeded in meeting the food needs of a growing world population partly because the public invested in the development of high-yielding varieties of food crops. Funding for the next food-production revolution in the early twenty-first century will require both public and private partners. This new funding paradigm creates new challenges, given the interest in and need for specialty or indigenous crops for developing countries that might attract public funding but are less likely to attract investment from the private sector. New models are needed to balance the roles of private and public funding in meeting the nutritional and food needs of developing countries.

Next steps to move agricultural biotechnology projects forward

Each workshop participant provided a number of recommendations in the areas of science, capacity building, opinion leader outreach, and funding to move modern biotechnology products closer to becoming part of the solution to providing nutritious foods for developing countries. Consensus emerged in several areas:

» Develop evidence to support the hypothesis that improving dietary diversity is an achievable and sustainable approach to improving health in developing countries.
» In developing this evidence, focus some research efforts on developing transformation systems for tropical food crops, particularly indigenous crops in areas of poor agricultural output and limited dietary diversity.
» Based on documented nutritional need, add specific nutrients to high-yielding crops and/or improve yields of nutrient-dense crops.
» Increase and sustain South–North and South–South interactions and cooperation to promote the development of infrastructure and regulatory frameworks, and to share scientific learning and genetic resources.
» Encourage opinion leaders to stress and fund capacity building in the area of food and nutrition in developing nations.
» Develop networks for sustained interactions between the agricultural and nutritional communities within developing nations and regions.
» Develop an intellectual property rights clearinghouse to facilitate technology transfer to developing nations.
» Build models that integrate biotechnology in portfolios, such as the plant-breeding and seed programs of the Food and Agriculture Organization of the United Nations, that include a broad array of tools for improving the availability of and access to diverse diets.
» Increase consumer awareness of, and confidence in, biotechnology by engaging stakeholders, local scientists, and journalists in discussions of the implications of the latest scientific and product developments, and increase industry understanding of stakeholder concerns and issues.
» Form a consortium of opinion leaders to encourage funding and cooperation on agricultural approaches that include, but are not limited to, modern biotechnology for the improvement of nutritional status, and seek a respected organization to convene.
» Examine other models, such as GAIN (Global Alliance for Improved Nutrition), to raise funds for public investment in new agricultural technologies.
» Develop a network whereby agriculture and nutrition leaders can communicate the imperative of meeting global food and nutrition needs and evaluate and recommend promising strategies.
» Continue the effort that began with this workshop by meeting at least annually to provide the necessary leadership development to bring agriculture and nutrition scientists together in a new health-promotion paradigm.
» Periodically review progress to determine the impact of new technologies and strategies to improve diet diversification, adequacy, and nutritional value.

Workshop participants

Dr. Baltazar Baltazar
Research Scientist
Pioneer
Tapachula Nayarit, Mexico

Dr. Stephen Beebe
Bean Breeder
Centro Internacional de Agricultura Tropical (CIAT) Headquarters
Cali, Colombia

Dr. Richard M. Black
Executive Director
ILSI North America
Washington, DC, USA

Dr. Howarth Bouis
Senior Research Fellow
International Food Policy Research Institute
Washington, DC, USA

Dr. Adolfo Chávez
Investigator
Instituto Nacional de la Nutrición
Mexico, DF, Mexico

Dr. Junshi Chen
Deputy Director
ILSI Focal Point in China
Chinese Academy of Preventive Medicine
Beijing, People's Republic of China

Dr. Claude M. Fauquet
Director
International Laboratory for Tropical Agricultural Biotechnology
Danforth Plant Science Center
St. Louis, MO, USA

Dr. Cutberto Garza
Professor
Division of Nutrition Sciences
Cornell University
Ithaca, NY, USA

Dr. Suzanne S. Harris
Executive Director
ILSI Human Nutrition Institute
Washington, DC, USA

Dr. Marzukhi Hashim
Biotechnology Center
Malaysian Agriculture Research and Development Institute
Kuala Lumpur, Malaysia

Dr. David Hoisington
Director, Applied Biotechnology Center and Bioinformatics
CIMMYT, Int.
Mexico, DF, Mexico

Dr. Juan Izquierdo
Plant Production Officer
Regional Office for Latin America and the Caribbean
Food and Agriculture Organization of the United Nations
Santiago, Chile

Dr. Gurdev S. Khush
Principal Plant Breeder and Head
Plant Breeding, Genetics and Biotechnology Division
International Rice Research Institute
Metro Manila, Philippines

Ms. Lucyna Kurtyka
Senior Project Manager
ILSI North America
Washington, DC, USA

Dr. Franco M. Lajolo
Professor
University of São Paulo
São Paulo, Brazil

Dr. David R. Lineback
Director
Joint Institute for Food Safety and Applied Nutrition
University of Maryland
College Park, MD, USA

Dr. Maureen Mackey
Global Lead, Nutrition Scientific Affairs
Monsanto Company
Buffalo Grove, IL, USA

Dr. Reynaldo Martorell
Robert W. Woodruff Professor of International Nutrition
Department of International Health
Rollins School of Public Health
Emory University
Atlanta, GA, USA

Dr. Christopher Ngichabe
Biotechnology Center
African Biotechnology Stakeholders Forum
Department of Biochemistry
University of Nairobi
Nairobi, Kenya

Ms. Marilia Regina Nutti
Director
EMBRAPA/CTAA Food Technology
Rio de Janerio, Brazil

Mr. James O. O'Chanda
Chairman of ABSF
Department of Biochemistry
College of Biological and Physical Sciences
University of Nairobi
Nairobi, Kenya

Dr. Irineo Torres Pacheco
Forestry, Agricultural and Livestock National Research Institute
Mexico, DF, Mexico

Mr. David Schmidt
Senior Vice President/Food Safety
International Food Information Council
Washington, DC, USA

Dr. Barbara O. Schneeman
Professor
University Outreach and International Programs
University of California–Davis
Davis, CA, USA

Dr. Prakash Shetty
Chief, Nutrition Planning, Assessment and Evaluation Service
Food and Nutrition Division
Food and Agriculture Organization of the United Nations
Rome, Italy

Ms. Eleanor Swatson
Horticulturist/Senior Agriculture Officer
Ministry of Food and Agriculture
Directorate of Crop Services
Accra, Ghana

Ms. Julia Tagwireyi
Nutrition Unit
Ministry of Finance and Economic Development
Harare, Zimbabwe

Dr. E-Siong Tee
Head, Cardiovascular, Diabetes and Nutrition Research Center
Institute for Medical Research
Kuala Lumpur, Malaysia

Dr. John A. Thomas
Professor Emeritus
University of Texas Health and Science Center
San Antonio, TX, USA

Dr. Jennifer A. Thomson
Professor of Microbiology
Department of Molecular and Cell Biology
University of Cape Town
Cape Town, South Africa

Dr. Ross M. Welch
Plant Physiologist
US Plant, Soil and Nutrition Laboratory
US Department of Agriculture
Cornell University
Ithaca, NY, USA

Mrs. Boon Yee Yeong
Executive Director
ILSI Southeast Asia
Singapore

Impact of fortification of flours with iron to reduce the prevalence of anemia and iron deficiency among schoolchildren in Caracas, Venezuela: A follow-up

Miguel Layrisse, María Nieves García-Casal, Hernán Méndez-Castellano, Maritza Jiménez, Henry Olavarría C., José F. Chávez, and Eglis González

Editorial note

Programs of cereal fortification as a means of reducing micronutrient deficiencies, particular of iron and folate, continue to expand to more and more countries, with the strong support of the international and bilateral agencies concerned with nutrition. It is widely accepted that the programs can contribute importantly to decreasing the prevalence of iron deficiency. However, there are almost no acceptable before and after data on the effectiveness of these programs. The 1996 report of the initial results of fortification of wheat and maize flour in Venezuela [1] still stands out as almost the only report of the effectiveness of cereal fortification in improving iron status.

The fortification program in Venezuela was instituted in 1993 in response to a deteriorating economic situation and evidence of a rising prevalence of iron deficiency and anemia. Both anemia and iron deficiency, as judged by serum ferritin, decreased by approximately 50% according to a survey using similar sampling methods in 1994, nearly two years later. However, the prevalence of anemia increased again in the following years, although iron deficiency did not. It was speculated that the continuing deterioration in the economic situation and in the diets of the population was a critical factor. The present paper reviews the results of surveys in 1997, 1998, and 1999 and their significance. It does resolve the paradox of increasing anemia without evidence of deterioration in iron status.

The initial observation of a decrease in anemia and improvement in iron status in Venezuela was possible only because of repeated national nutrition surveys before the fortification program was initiated. There is an urgent need for more good baseline data on iron status before fortification programs are introduced, so that by subsequent surveys the relative effectiveness of iron fortification of cereals can be better understood.

Editor

Reference

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Abstract

In Venezuela, a severe economic crisis starting in 1983 provoked a progressive reduction in the quantity and quality of food consumed by people from the low socioeconomic strata of the population. This situation resulted in a continuous increase in the prevalence of iron deficiency in the 1980s and 1990s. In 1993, an iron-fortification program was started, in which precooked corn and white wheat flours were enriched with iron, vitamin A, thiamine, niacin, and riboflavin. White wheat flour was enriched with the same nutrients, except for vitamin A. In 1996 we published the results of the impact of fortification of precooked corn and white wheat flours on the prevalence of anemia and iron deficiency in the population. A survey carried out in Caracas in 307 children aged 7, 11, and 15 years showed that the prevalence of iron deficiency measured by serum ferritin concentration dropped from 37% in 1992 to 16% in 1994, only one year after the iron-fortification program began. The prevalence of

Miguel Layrisse (deceased February 22, 2002; see obituary in the *Food and Nutrition Bulletin* (2002;23(3):332–3) was affiliated with the Centro de Medicina Experimental, Laboratorio de Fisiopatología, Instituto Venezolano de Investigaciones Científicas (IVIC), in Caracas, Venezuela. María Nieves García-Casal is affiliated with the same center. Hernán Méndez-Castellano, Maritza Jiménez, and Henry Olavarría C. are affiliated with FUNDACREDESA in Caracas. José F. Chávez and Eglis González are affiliated with the Instituto Nacional de Nutrición in Caracas.

anemia, as measured by the hemoglobin concentration, diminished from 19% to 10% during the same period. This article reports the results of three other surveys carried out in 1997, 1998, and 1999 on children of the same age and socioeconomic groups that were evaluated in 1990, 1992, and 1994. There were no significant differences in anemia or iron deficiency among the last three surveys. The prevalence results from the last seven years seem to indicate that, after a dramatic reduction in 1994, iron deficiency tended to stabilize, while the prevalence of anemia increased to the same level found in 1992, before the fortification program started.

Key words: Flour fortification, iron, ferritin, iron deficiency, anemia

TABLE 1. Enrichment of food vehicles in Venezuela

Nutrient	Precooked maize flour	White wheat flour
Vitamin A (IU/kg)	9,500	—
Thiamine (mg/kg)	3.1	1.5
Riboflavin (mg/kg)	2.5	2.0
Niacin (mg/kg)	51.0	20.0
Iron[a] (mg/kg)	50.0	20.0

a. As ferrous fumarate until 1994. Since then, 30 mg/kg as ferrous fumarate and 20 mg/kg as electrolytic iron.

Introduction

Iron deficiency affects more than 2 billion people throughout the world and is severe enough to cause anemia in 1 billion people [1, 2]. The causative factor is the poor bioavailability of iron from cereal-based diets, which are the staple food in many developing countries [3]. Strategies for combating iron deficiency include control of parasitic infections, especially hookworm, improvement of sanitation, iron supplementation, and iron fortification [4–6]. Of these strategies, iron fortification of basic foods is the most economical and most convenient approach and has the advantage that it does not require changes in the food habits of the individual [6].

As reported previously, beginning in 1960 a progressive reduction in the prevalence of iron deficiency was observed in Venezuela [6–10]. However, the economic crisis that began in 1983 with currency devaluation led to a progressive reduction in the quality and quantity of the diet consumed by people of low socioeconomic strata, who currently make up 80% of the Venezuelan population. This resulted in a continuous increase in the prevalence of iron deficiency in the 1980s and 1990s. As a result, in 1993 the Venezuelan Government nominated a special commission for the enrichment of food (CENA). A program of iron fortification was started the same year to enrich precooked corn flour with iron, vitamin A, thiamine, niacin, and riboflavin. White wheat flour was enriched with the same nutrients, except for vitamin A (table 1).

In 1996, we reported the impact of this fortification program on the prevalence of anemia and iron deficiency among children in Caracas during the first two years of the program [11]. The prevalence of anemia, as judged by plasma hemoglobin, decreased from 37% to 15%; the prevalence of iron deficiency, as measured by serum ferritin, decreased from 19% to 10%. This paper describes the results of three surveys carried out in the following three years (1997–99) on children of the same age and socioeconomic group who were sampled in the same manner as in 1990, 1992, and 1994.

Methods

Subjects

Three national surveys were carried out in 1997, 1998, and 1999, which evaluated 4,992 children and adolescents from 1 to 15 years of age. The impact of the fortification program was evaluated by comparing previous published results [11] with data obtained from these three surveys. Only 7-, 11-, and 15-year-old children and adolescents from labor (IV) and low (V) socioeconomic strata of the Caracas population were evaluated. In all six surveys, public schools were selected randomly from the same list, and a random sample of children was drawn. The subjects were classified according to age, sex, and socioeconomic stratum [12]. Those in the two lower strata were selected to give blood samples.

Among other hematological tests, the hemoglobin concentration [13] was measured in all subjects included in the surveys (590 subjects in 1997, 478 in 1998, and 545 in 1999). The serum ferritin concentration [14] was determined in most of the samples (571 samples in 1997, 466 in 1998, and 537 in 1999).

Anemia was defined as a hemoglobin concentration below 115 g/L for 7-year-old children of both sexes, 120 g/L for 11- and 15-year-old females, and 125 and 130 g/L for 11- and 15-year-old males, respectively. The cutoff for iron deficiency was a serum ferritin concentration less than 10 μg/L for 7- and 11-year-old males and females, and less than 12 μg/L for 15-year-old males and females.

Statistical analysis

Statistical analysis of the serum ferritin concentration of samples from the 1997, 1998, and 1999 surveys of the Caracas population [5, 13] was performed by logarithmic procedures. The chi-square test with the Bonferroni correction as a post-test was used to compare the prevalence of iron deficiency and anemia between surveys. Analysis of variance (ANOVA) was used for the comparison of hemoglobin and ferritin concentrations among surveys.

Results

The corn flour industry produces 60 million tons per year, of which 10 million tons of processed corn are transformed into 700,000 tons of corn flour. Wheat is mainly imported from the United States and Canada, and 12 million tons of processed wheat produces 700,000 tons of wheat flour. The cost of the micronutrient mixture added to the flours represents less than 1% of the market selling price and is absorbed by the industry.

From 1993 (when the fortification program started) to 1999, random samples of commercial flour packages were taken approximately every two months from shelves at food stores by trained persons from the National Institute of Hygiene and the National Institute of Nutrition and were analyzed in the laboratory for iron concentration at the consumer level. The analysis of iron content showed that it ranged between 80% and 120% of the expected value.

Changes in the prevalence of anemia and iron deficiency in children and adolescents from the low socioeconomic strata of the Caracas population are shown in table 2. Because the results were essentially the same for children and adolescents and no sex differences in response were observed, the data were pooled for further analysis. There were no significant differences in anemia or iron deficiency among the last three surveys. The prevalence results from the last seven years indicate that, after a dramatic reduction in 1994, iron deficiency, as judged by serum ferritin, tended to stabilize. The prevalence of anemia also diminished dramatically from 1992 to 1994, but for the last three surveys it returned to the value that was reported before the fortification program was started.

The median ferritin concentration during the last seven years had a clear tendency to increase, even though the increase was small for the last three surveys (table 3). This index was significantly increased in 1997, 1998, and 1999 as compared with 1992, when the iron-fortification program had not been started.

Discussion

For an iron-fortification program to be successful, it is important to choose food vehicles that are consumed daily, to select an iron compound that is well absorbed, and to have the ability to control the enrichment. The Venezuelan program of nutrient enrichment met all three criteria. The overall population consumes precooked corn flour bread, and the target low-income population eats wheat flour as either bread or pasta.

The impact of iron fortification on the prevalence of iron deficiency and anemia deserves several comments. In 1992, one year before the iron-fortification program started, iron reserves had decreased to a median of 15 μg/L. After fortification, they increased markedly to 22 μg/L in 1994. This occurred despite the fact that the diet consumed by this population continued to deteriorate due to the severe reduction in quality and quantity of the diet consumed by the labor and lower socioeconomic strata of the population.

As evidence for this, FUNDACREDESA (Foundation for the Study of National Growth and Human Development) calculated the cost of a monthly base diet for a family of five (father, mother, and three children). This diet contains only locally produced foods; the main constituents are corn flour, rice, plantain, potatoes, milk, fruit, meat, vegetables, and eggs. The average macronutrient contents are 2,200 kcal, 65 g of protein, 343 g of carbohydrate, and 66 g of fat. In 1994 the monthly cost of this diet was 989 Bolívares (Bs.), equivalent to US$7. In 1998 the cost increased to 142,000 Bs. (US$259). During this period, 10% of the middle class, 20% of the labor class, and 30% of the low socioeconomic class would not have been able to afford this base diet to meet their nutritional requirements [12, 15].

It has been shown that the absorption of iron from ferrous fumarate is similar to that from ferrous sulfate when these supplements are added to corn or wheat flours [16]. The industrial process of preparing flour permits full control of the fortification ingredients. Ferrous fumarate had been used to fortify flour in Caracas for less than six months before the recommendation was made by the Venezuelan Institute for Scientific Research to use it on a national scale.

During the first year of iron fortification, a problem was observed in two regions of the country where hard water is used for making maize bread in the evening for consumption on the afternoon of the next day. The bread turned slightly dark the day after it was baked; this change was confirmed in the laboratory. Fortunately, the hard water responsible was limited to only two regions. About 22,000 people, less than 1% of the population of Venezuela, were affected. Nevertheless, in response to this problem, the iron-fortification pattern of the maize flour was changed in 1994. The precooked corn flour was enriched with 30 mg/kg of iron as ferrous fumarate and 20 mg of electrolytic iron. This pattern of iron fortification continued from February 1994 to 1998 without any further problem with the fortification.

There are some examples in the literature of the early effects of iron-fortification programs [16, 17]. Garby and Areekul [18] reported the effect of fortification of fish sauce with NaFe-EDTA in a Thai village for one

TABLE 2. Prevalence of anemia and iron deficiency in children and adolescents from the low socioeconomic strata of the Venezuelan population, according to surveys conducted in 1992, 1994, 1997, 1998, and 1999

			Anemia			Iron deficiency		
Year	Age (yr)	Sex	No. evaluated	No. affected	%	No. evaluated	No. affected	%
1992[a]	7	M & F	72	10	13.9	72	26	36.1
	11	M	39	12	30.7	39	10	25.6
	11	F	52	12	23.1	52	26	50.0
	15	M	51	5	9.8	51	16	31.4
	15	F	68	12	17.6	68	27	39.7
	Total[b]		282	51	18.1	282	105	37.2
1994[a]	7	M & F	91	3	3.3	91	1	13.2
	11	M	65	10	15.4	65	8	12.3
	11	F	65	7	10.8	65	5	7.7
	15	M	30	1	3.3	30	1	3.3
	15	F	66	9	13.6	66	24	36.8
	Total[b]		317	30	9.3	317	50	15.8
1997	7	M	64	8	12.5	63	9	14.3
	7	F	72	8	11.1	71	6	8.5
	11	M	98	24	24.5	93	4	4.3
	11	F	85	18	21.2	83	9	10.8
	15	M	115	3	2.6	110	10	9.1
	15	F	156	25	16.0	151	42	27.8
	Total[b]		590	86	14.6	571	80	14.0
1998	7	M	69	4	5.8	64	4	6.3
	7	F	48	5	10.4	47	5	10.6
	11	M	69	26	37.7	66	6	9.1
	11	F	58	6	10.3	58	2	3.4
	15	M	112	16	14.3	112	9	8.0
	15	F	122	32	26.2	119	26	21.8
	Total[b]		478	89	18.6	466	52	11.2
1999	7	M	84	12	14.3	83	18	21.7
	7	F	93	8	8.6	92	17	18.5
	11	M	108	32	29.6	107	4	3.7
	11	F	89	8	9.0	88	11	12.5
	15	M	65	11	16.9	63	8	12.7
	15	F	106	22	20.8	104	25	24.0
	Total[b]		545	93	17.1	537	83	15.5

a. Data from 1992 and 1994 surveys have been previously published [11].
b. Totals are weighted means.
There were no significant differences between years in the prevalence of anemia or iron deficiency.

year. The fortification produced an additional intake of approximately 10 mg of iron per day, and after one year the packed cell volume increased by about 1.5% as compared with the control population. In a trial of iron fortification in three Central America communities, sugar was the food vehicle enriched with NaFe-EDTA; the additional intake provided approximately 3 mg of iron per day. After 20 months they found a significant increase in the serum ferritin concentration in the populations of all three communities [19]. Finally, in a South African iron-fortification trial [20, 21], curry powder was fortified with NaFe-EDTA and tested in an urban Indian community whose daily intake of iron via fortification was 7 mg. After one year, there were significant increases in the hemoglobin concentration to a mean of 15 g/L and in the ferritin concentration to a mean of 15 μg/L.

In summary, in the Venezuelan population, in spite of the economic crisis of the last seven years, the iron-fortification program was sufficient to reduce

TABLE 3. Statistical analysis of ferritin concentration in total samples of children 7, 11, and 15 years of age from the 1992, 1994, 1997, 1998, and 1999 surveys

Survey	Values	Mean	SE	Median	95% confidence interval	*n*
1992	Arithmetic	18.01	0.82	15	16.39–19.64	282
	Geometric	13.46[d]	1.05	15	12.22–14.83	
1994	Arithmetic	25.20	0.86	22	23.51–26.89	317
	Geometric	20.54[c]	1.04	22	18.96–22.25	
1997	Arithmetic	28.67	0.74	24	27.21–30.13	571
	Geometric	21.91[a,b,c]	1.03	24	20.51–23.38	
1998	Arithmetic	33.98	1.03	28	31.50–36.46	466
	Geometric	26.08[a]	1.26	28	24.26–28.02	
1999	Arithmetic	31.64	0.89	27	28.27–31.76	537
	Geometric	24.1[a,b]	1.03	27	21.03–24.30	

Means with no letters in common are significantly different ($p < .001$).

the prevalence of iron deficiency, as judged by serum ferritin, to 16% and to maintain the median ferritin concentration at 27 µg/L.

The prevalence of anemia was reduced during the first two years of fortification, but it returned to prefortification levels for the last three surveys. This could be due to the continuous deterioration of food consumption (even corn flour, the main staple food in Venezuela, showed a drop in sales volume of 10% during 1998–99), the impressive epidemic of dengue affecting Venezuela for the last five years, and other viral infections. C-reactive protein was measured in the 1998 and 1999 surveys. Samples were taken from all subjects with anemia (with or without iron deficiency). In 1998, 89 samples were analyzed, and 3 were positive. In 1999, 6 of 93 samples were positive.

Another factor affecting the prevalence of anemia could be the change in the fortification pattern, which included a proportion of a less available source of iron. In spite of the fact that conditions in the country continue to deteriorate, this fortification program has improved iron stores and prevented the prevalence of anemia from increasing further.

There is still the paradox that anemia is returning despite the improvement in iron stores. We suspect the 37-fold increase in the cost of diets led to other micronutrient deficiencies that increased the prevalence of anemia even though iron deficiency decreased. Unfortunately, we do not have the baseline or current micronutrient data to determine this, but we will next evaluate the current status of other micronutrients in an effort to explain the paradox.

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Time trends in the intrafamily distribution of dietary energy in rural India

K. Vijayaraghavan, B. Surya Prakasam, and A. Laxmaiah

Abstract

The intrafamily distribution of dietary energy in 5,458 households from seven states in India was assessed from 24-hour dietary recall data collected by the National Nutrition Monitoring Bureau during 1996–97. The energy consumption, expressed as percentage of recommended dietary intake (%RDI), of preschool children, schoolchildren, and adolescents was compared with that of adult men and women in the same households. Time trends in the intrafamily distribution of dietary energy were assessed by comparing the data with those collected in 1975–80 using the same procedures in the same villages. About one-third of the preschool children had an inadequate intake of energy, even when their adult counterparts had an adequate intake, whereas only about 7% of the preschoolers and their parents were consuming inadequate amounts of energy. The extent of energy inadequacy was much less in adolescents and school-age children than in preschool children. This was true even when the adults in the same households had an adequate energy intake. In 1996–97, there was a significant increase in the proportion of households with preschool children consuming inadequate energy, although both adult men and women were consuming energy-adequate diets as compared with the dietary data collected in the same villages in 1975–80. The results indicate the need to provide effective nutrition education for parents regarding the nutritional needs of their children.

Key words: Households, recommended dietary intake (RDI), kilocalories (kcal)

Introduction

Similar surveys by the National Nutrition Monitoring Bureau (NNMB) in the same rural villages between 1975–80 and 1996–97 in different regions of the country revealed a substantial decline in the prevalence of severe undernutrition, particularly among preschool children [1]. In countries like India, where there is widespread undernutrition, intrafamily distribution of food among different household members has long been a concern of nutritionists and sociologists [2]. Women and children are considered a deprived group, as judged by the malnutrition among them, in comparison to adult and adolescent males [3]. In India, it was earlier reported that intrafamily distribution of diets was unfavorable for preschool children, perhaps due to ignorance or to sociocultural factors [4].

The intrafamily distribution pattern of energy intakes among preschool and school-age children and adolescents vis-à-vis adult males and females of the same households was studied. Adolescents are a nutritionally at-risk group rarely identified in intrahousehold studies. In addition, family distribution of dietary energy intakes from the two surveys is compared.

Methods

Trained interviewers obtained 24-hour food intakes from individuals in different age groups in all the households surveyed in seven states of India. The validity of the 24-hour recall method for dietary surveys in Indian situations has been established [5]. All of the food consumed during the previous 24 hours was noted, with the help of standardized measuring cups. Because only one 24-hour dietary recall was obtained from each subject, the mean values are representative, but the data cannot be taken to represent an individual family.

The respondent for the diet survey was the woman responsible for cooking and distributing food to different members in the family. In the households selected for analysis, at least one preschool child (1–4 years), one school-age child (5–11 years) or one adolescent (12–17 years), as well as one adult man (18 years or older) and

The authors are affiliated with the Division of Field Studies at the National Institute of Nutrition, Hyderabad, India.

one adult woman (18 years or older) had partaken of the family meal. In the households with more than one adult of the same sex, the average intakes of all the adults of the same sex were computed. Because only 1.2% of adult men and 1.4% of adult women belonged to such households, this did not affect the results.

The nutritive value of the foods consumed was calculated using the Indian food composition table [6]. Energy intake was expressed as a percentage of the recommended dietary intake (RDI) [7] for individuals of corresponding age, sex, physiological status (including pregnancy and lactation), and physical activity.

Persons whose energy intake was at least 70% of the RDI level (≥ mean –2 SD of RDI) were considered to have adequate energy status. Households were categorized according to the energy adequacy status of each child or adolescent household member as compared with the adult pair within each household.

Results

Energy consumption

There were 5,458 pairs of adults and other individuals of different ages (1,696 preschool children, 2,356 school-age children, and 1,406 adolescents) whose dietary data were compared to assess intrafamily distribution of dietary energy in households.

TABLE 1. Mean energy consumption among Indian children, adolescents, and adults

	Males		Females	
Age group	kcal	%RDI	kcal	%RDI
Preschool	889	65.5	897	66.4
School-age	1,464	75.9	1,409	75.1
Adolescent	2,065	84.6	1,670	91.6
Adult	2,226	91.8	1,923	102.6

The mean intakes of energy in different age groups are presented in table 1. The diets in all groups were deficient in energy as compared with the RDI. The deficit was highest in the diets of preschool children. No sex differences in the energy intakes of preschool children and schoolchildren were observed. However, the intakes were marginally more adequate in female adolescents and adults.

Energy adequacy of children and adolescents vis-à-vis adults

About 80% of adult males, 86% of adult females, 73% of adolescents, 54% of school-age children, and 36% of preschool children had adequate energy intakes (≥ 70% of RDI). Thus, both preschool and schoolage children were at a disadvantage. Surprisingly, preschool children in 43% of the households were energy inadequate, even when the adults of both sexes had adequate energy in their diets. Moreover, when the energy consumption of both the adult man and the adult woman in the household was inadequate, only 1% of the preschool children had adequate energy intake. Similarly, the proportion of households in which the preschool child was consuming adequate calories while one of the adults was consuming inadequate calories was negligible, ranging from 1% to 3% (table 2).

In about 31% of the households, both preschool children and adult males and females had adequate energy intakes, whereas in about 7% of these households, preschool children, schoolchildren, and adolescents had inadequate energy intakes. The proportion of adults consuming adequate energy diets as compared with schoolage children and adolescents was 47.3% and 61.6%, respectively (table 2).

The proportion of children with inadequate energy intake when adults in the same household had adequate energy intake showed a gradual decline from 43% in

TABLE 2. Distribution (%) of children and adolescents according to percent with adequate energy intake vis-à-vis adults

Energy status			Age group		
Adult males	Adult females	Children/ adolescents	Preschool ($n = 1,696$)	School-age ($n = 2,356$)	Adolescents ($n = 1,406$)
Adequate	Adequate	Adequate	31.1	47.3	61.6
Adequate	Adequate	Inadequate	42.9	27.4	13.2
Adequate	Inadequate	Adequate	1.4	1.4	2.1
Adequate	Inadequate	Inadequate	4.2	2.2	1.4
Inadequate	Adequate	Adequate	2.9	4.7	7.3
Inadequate	Adequate	Inadequate	9.3	8.8	6.2
Inadequate	Inadequate	Adequate	1.0	1.2	2.2
Inadequate	Inadequate	Inadequate	7.2	7.0	6.0

$\chi^2 = 398.6$, $p < .001$.

preschool children to 13% in adolescents. There were no significant sex differences in the distribution of dietary energy among preschool children vis-à-vis adults. Irrespective of sex, a higher percentage of preschool children had inadequate energy intakes.

It is noteworthy that about 4% to 6% of adult males had adequate energy intakes in households in which the adult female had inadequate energy intake. However, 12% to 14% of adult females were consuming adequate energy when adult males in the same household had inadequate energy intakes. Since these results were based on comparison of adult versus child or adolescent pairs in the pooled data, they do not indicate the relationship between the groups within a single household. Analysis was done of the distribution of energy intakes among the households in which members of each age and sex group were present. Although this considerably reduced the sample size, the results were essentially similar.

Literacy status of the mother

The literacy status of the mother did not influence the intrafamily distribution of energy adequacy among preschool children vis-à-vis adults (table 3). However, there was less inadequacy among both adults and children in households where the women had a high school education or more.

Time trends in the intrafamily distribution of energy

The proportion of households in which both the adult man and the adult woman had an adequate energy intake increased from 56.4% in 1975–79 to 73.9% in 1996–97. Similarly, the proportion of households in which both the adult man and the adult woman had an inadequate energy intake decreased from 22.5% to 8.2%. The proportion of households in which all individuals had inadequate energy intake was much lower in 1996–97 (7%) than in 1975–80 (19%) ($p < .001$). However, there was a significant increase between the two time periods in the proportion of households in which the preschool children had an inadequate energy intake while both the adult man and the adult woman had energy-adequate diets; the proportion was 25.4% in 1975–80 and 42.9% in 1996–97 ($p < .001$) (table 4 and fig. 1).

The energy consumption of preschool children and adults is compared in table 5. The preschool child is at a disadvantage compared with the adult. In households in which both the adult man and the adult woman had adequate energy intakes, a large proportion of preschool children of all ages from one to four years had inadequate energy intakes.

TABLE 3. Comparison of energy adequacy of preschool children (%) and adults according to mother's literacy

Energy status			Mother's literacy status		
Adult male	Adult female	Preschool child	Illiterate (n = 1,031)	Primary and secondary school (n = 452)	≥ High school (n = 213)
Adequate	Adequate	Adequate	31.4	29.0	33.3
Adequate	Adequate	Inadequate	42.0	42.9	47.4
Inadequate	Inadequate	Inadequate	7.2	8.4	4.7
Other combinations			19.4	19.7	14.6

$\chi^2 = 7.43$, $p > .05$.

TABLE 4. Time trends in intrafamily distribution of energy (%) for preschool children and adults

Energy status		Period	
Adult male/female	Preschool child	1975–80 (n = 2,465)	1996–97 (n = 1,696)
Both adequate	Adequate	31.1	31.0
Both adequate	Inadequate	25.4	42.9
Either one inadequate	Adequate	6.1	4.3
Either one inadequate	Inadequate	14.9	13.5
Both inadequate	Adequate	3.4	1.1
Both inadequate	Inadequate	19.1	7.2

$\chi^2 = 223.4$, $p<.001$.

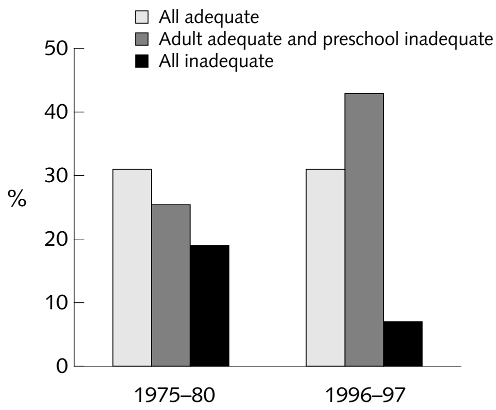

FIG 1. Time trends in intrafamily distribution of energy for preschool children and adults

Discussion

The intrafamily distribution of dietary energy was particularly unfavorable for preschool children and, to a lesser degree, for school-age children. Inadequate energy intake was much more frequent among preschool children than among adults of either sex. More importantly, in about 43% of the families, the preschool child was not getting adequate amounts of energy, even when energy consumption by the adults was adequate. In 7% of the families, men, women, and children had inadequate energy intakes, which could be taken as an indication of inadequate access to food in the household. The reduction in this proportion seen in the second survey indicated that there has been improvement, albeit marginally, in the resources in some of the households.

These results are consistent with those reported earlier of an improvement in energy intake by members of almost all age groups over time [8]. Despite such a positive change, there has been an increase in the proportion of preschool children with inadequate energy intakes even in households where the adults have adequate energy intakes. This indicates that most of the energy inadequacy among the preschool children was not due to lack of food at home. Rather, it was due to lack of awareness of their child's needs on the part of the parents.

The calculated energy intakes of the preschool children do not include the contribution of breastmilk. Earlier studies showed that in rural communities the children are breastfed up to 24 months of age. Hence, it is possible that a number of the one- to two-year-old children received some energy from breastmilk. However, the existence of unfavorable distribution of energy intake among three- to five-year-old children, whose breastmilk consumption would be negligible (table 5), indicates that the failure to include intake of breastmilk in the calculation is not the reason for the unfavorable intrafamily distribution of energy in young children. It is obvious that the preschool child is more at risk of not obtaining an adequate share of the family diet than either a school-age child or an adolescent, because older children can eat and find food more readily on their own.

Adult men consumed more food than adult women because of their higher energy requirements, but there was no evidence for discrimination against women in the distribution of the family food. On the contrary, the average calorie intakes of women, considering their requirements, were marginally higher (94% of RDI) than those of men (85%).

Although there has been no change over the last two decades in the proportion of households in which preschool children and adult men and women all consumed diets with adequate energy, there was an unexpected increase in the proportion of households in which preschool children had inadequate energy intake, even when both adults had adequate energy intakes. This indicates a lack of awareness of the dietary needs of the preschool child and the need for effective nutrition education for parents regarding the nutritional needs of their children. In this study, all members of the family benefited equally from increased education of the mother.

TABLE 5. Adequacy (%) of energy consumption of preschool children by age according to adequacy of adult consumption

Energy status		Preschool child's age (yr)			
Adult male/female	Preschool child	1+ (*n* = 393)	2+ (*n* = 410)	3+ (*n* = 474)	4+ (*n* = 419)
Both adequate	Adequate	13.0	33.9	42.5	32.0
Both adequate	Inadequate	57.7	41.1	33.1	42.1
Either one inadequate	Adequate	1.8	4.6	6.6	4.0
Either one inadequate	Inadequate	17.6	12.9	10.2	14.0
Both inadequate	Adequate	1.0	1.2	1.3	0.5
Both inadequate	Inadequate	8.9	6.3	6.3	7.4

$\chi^2 = 97.6$, $p < .001$.

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Standardized evaluation of iodine nutrition in West Africa: The African phase of the ThyroMobil program

François M. Delange, Théo Ntambwe Kibambe, André Ouedraogo, Alfred Acakpo, Machikourou Salami, and Peter L. Jooste

Editorial introduction

The difficulty of implementing nutrition intervention and control programs in Southern Africa is well known. Given the limited success of many programs in the region, the virtual elimination of iodine-deficiency disorders and 98% access to iodated salt in Benin and Burkina Faso is extremely encouraging. The 84% to 94% access to iodated salt in Togo and Mali and a substantial reduction in endemic goiter are also very encouraging. This should serve as an example and stimulus to complete the task of eliminating iodine-deficiency disorders as a public health problem in the region.
Editor

Abstract

Extensive programs of iodine supplementation by iodated salt have been implemented in Africa during the last decade. The present work evaluated their effectiveness in Benin, Burkina Faso, Mali, and Togo. A van equipped with a sonographic device visited 39 sites in the four countries. The prevalence of goiter was evaluated on the basis of the determination of thyroid volume by ultrasonography in 4,011 randomly selected 6- to 12-year-old schoolchildren of both sexes in the 39 sites. The concentration of urinary iodine was measured in 1,545 of these children. The iodine content of table salt collected at home by the children was measured by test kits in 3,202 salt samples, 415 of which were also analyzed by titration. Based on the results obtained by the kits, 83.7% to 97.9% of the salt samples contained iodine. However, the test kits had a low sensitivity and specificity in comparison with titration. The median urinary iodine was within an acceptable range (100–300 μg/L) in the four countries, but almost one-third of the values were still below normal. The prevalence of goiter was normal (< 5%) in Benin and Togo, and it was 22.4% and 13.4%, respectively, in Burkina Faso and Mali. These results indicate marked improvement of the status of iodine nutrition in comparison with the situation reported only a few years ago in the same countries, but quality control of the iodine content of salt and monitoring of the iodine status of the populations need to be improved.

Key words: West Africa, iodine deficiency, iodated salt, thyroid ultrasound, urinary iodine, iodine excess

Introduction

The disorders induced by iodine deficiency constitute an important public health problem in the world, especially because iodine deficiency represents a cause of preventable mental retardation [1–3]. The problem used to be particularly severe in Africa. In 1990, 181 million people (32.8% of the population) were affected by iodine deficiency; 15.6% of the population had a goiter, and 0.2% developed endemic cretinism [4, 5].

During the last decade, major efforts have been made toward the goal of sustainable elimination of iodine-deficiency disorders in the world, including Africa [6–8]. Combined programs of iodine supplementation using iodized oil, iodated salt, and even iodized water were implemented in the most severely affected African countries [9, 10]. However, the effectiveness of these measures and the risk of iodine excess due to the superimposition of the different programs have been insufficiently evaluated in West Africa [11, 12].

Our work constitutes the first approach to a standardized evaluation of iodine nutrition in West Africa

François M. Delange is affiliated with the International Council for Control of Iodine Deficiency Disorders (ICCIDD) in Brussels, Belgium. Théo Ntambwe Kibambe is affiliated with ICCIDD in Kinshasa, Democratic Republic of Congo. André Ouedraogo, Alfred Acakpo, and Machikourou Salami are affiliated with the Centre Régional de Recherche en Alimentation et Nutrition (CRAN) in Lome, Togo. Peter L. Jooste is affiliated with the Nutritional Intervention Research Unit, Medical Research Council in Tygerberg, Cape Town, South Africa.

by using the ThyroMobil model, previously used in 24 countries in Europe, Asia, and Latin America [8]. In this model, a van equipped with a sonographic device, a computer for processing the thyroid measurements on the spot, and facilities for the collection and storage of urine samples for urinary iodine assays visits different sites in different countries. All thyroid sonographies are performed by the same investigator, and all urinary iodine assays are performed in the same laboratory. This standardized evaluation of iodine nutrition allows a valid comparison of the results obtained in different countries and even in different continents [13].

The present work reports the results obtained in four West African countries: Benin, Burkina Faso, Mali, and Togo. The aims of the study were as follows:

» To evaluate the present status of iodine nutrition in West Africa by using the methods recommended by WHO/UNICEF/ICCIDD [1]. Particular attention has been paid to the three major indicators: access to iodated salt and evaluation of the iodine content of the salt at the household level, urinary iodine concentration, and the prevalence of goiter as determined by ultrasound;
» To propose normative values for thyroid volume in West African iodine-replete populations, in this case in coastal areas of Togo and Benin;
» To increase the awareness of the national populations and authorities of the problem of iodine-deficiency disorders.

Methods

Global organization of the project

The logistical basis for the organization of the project has been the Centre Régional de Recherche en Alimentation et Nutrition (CRAN) in Lome, Togo. The countries under investigation—Benin, Burkina Faso, Mali, and Togo—were selected on the basis of the existence of marked differences in the past in their iodine intake, their accessibility by road with the ThyroMobil van, and because of sustained and easy contacts with CRAN.

Table 1 summarizes the present demographic and geographic characteristics of the four countries and the latest information on the status of their control of iodine-deficiency disorders at the time of the start of the present survey.

Each country involved in the project was represented by a national investigator who selected 9 or 10 sites located in previously endemic areas and accessible to the van. Groups of approximately 100 randomly selected schoolchildren of both sexes and aged 6 to 12 years were investigated at each site. In addition, schoolchildren were examined in Lome, Togo, and Cotonou, Benin, two coastal cities in which marine fish is a staple food and in which there is no past history of iodine deficiency, in order to obtain normative values for thyroid volume in iodine-replete schoolchildren in Africa.

The ThyroMobil van previously used in Europe [13], equipped with a sonographic device, a computer for processing the thyroid measurements on the spot, and facilities for the collection and storage of urine samples, visited the schools in all sites in the four countries under investigation. The fieldwork was conducted between October and December 1999.

The ThyroMobil was usually located in the schoolyards of the sites under investigation, and the children underwent sonography in that place. Urine samples for determination of iodine were collected just before or after sonography. They were stored in the freezer of the van until they were sent together to the Nutritional Intervention Center of the Medical Research Council in Cape Town, South Africa, where all the iodine determinations were performed.

The children were also asked to supply the investigators with a casual sample of the salt used at home, and its iodine content was estimated by using a rapid test kit.

TABLE 1. Present demographic and geographic characteristics and information on iodine nutrition in the four countries under investigation at the time of the present survey

Country	2002 population (millions)	Area (km^2 × 103)	Goiter prevalence	Urinary iodine (μg/L)	Iodated salt			
					Imported (%)	Legislation year (ppm)	Access at household level (%)	Additional iodine supplementation
Benin	6.27	112	19% in 1994	40	80	1994 (50–80)	35	Iodized oil
Burkina Faso	11.55	274	Up to 57% in 1987	Low?	100	1996 (150)	22	Iodized oil
Mali	10.83	1,240	35%–92% in 1996	< 25	> 90	1995 (50)	20	Iodized oil and water
Togo	4.53	56	39% in 1982	7–34	100	1996 (80–100)	< 10	Iodized oil

Source: refs. 9–11, 14, 15.

In order to increase the awareness of the public of iodine nutrition, national health authorities, teachers, and the public were invited to visit the van, and conferences on iodine-deficiency disorders were provided by the team of investigators there and in the capitals of the four countries.

The investigation was approved by the ethical committee of the University of Brussels and by the national ministries of health and education of the four countries.

Methods

Patients and samples

The investigation included 4,011 schoolchildren of both sexes, aged 6 to 12 years, with a slight preponderance of males and a mean age of 8.9 years, from 39 sites in the four countries (85 to 195 per site), including 96 in Lome (Togo) and 195 in Cotonou (Benin). Thyroid ultrasonography was performed on all children. Urine samples for determination of iodine content were collected from 1,545 randomly selected schoolchildren from the 39 sites, including all children investigated in Lome and Cotonou.

A total of 3,202 samples of salt used at home were provided by the schoolchildren. All these samples were tested in the field for their iodine content by semi-quantitative test kits. The percentage of these samples containing iodine was used as an index of the access to iodated salt at the household level. In addition, 415 randomly selected salt samples were brought to the CRAN laboratory, where their quantitative iodine content was measured by titration and compared with the results obtained by the test kits.

Thyroid volume

Thyroid volume was estimated using real-time sonography according to the method of Brunn et al. [16] with a Siemens Sonoline SI-400 (Siemens, Erlangen, Germany), using a 7.5-MHz linear array transducer. All thyroid ultrasounds were performed by one of the authors of this paper (T.N.K.), who had been extensively trained in thyroid ultrasonography in the Department of Radiology, University Hospital Saint-Pierre, Brussels, Belgium. The revised sonographic criteria reported by Zimmermann et al. [17, 18] were used in this study. Longitudinal and transverse scans were performed, allowing the measurement of the depth (d), width (w), and length (l) of each lobe. The volume of the lobe was calculated by the formula: V (ml) = 0.479 × d × w × l (cm). The thyroid volume was the sum of the volumes of both lobes. The volume of the isthmus was not included.

A thyroid was considered goitrous when its volume was greater than the 97th percentile for age and sex, using the modification by Zimmerman et al. [18] of the WHO/ICCIDD criteria [19].

Urinary iodine

The urinary iodine concentration was measured by manual acid digestion and spectrophotometric detection of iodine by ceric ammonium reduction in the Sandell-Kolthoff reaction [20, 21].

Iodine in salt

We used the semiquantitative test kits produced by MBI Chemicals (Chennai, India) and the retest solution for iodate in case of absence of detectable iodine at the first testing. As recommended by WHO/UNICEF/ICCIDD [1], the free iodine liberated from the salt in acid conditions was titrated with thiosulfate.

Statistical methods

The usual statistics (proportions, mean, standard deviation, median, and range) were used to describe the data [22].

Results

The overall results of the study are summarized in table 2.

TABLE 2. Number of sites, sample sizes in the four countries, and overall summary of the results of the present survey

Country	No. of sites	No. of children	Access to iodated salt (%)[a] (n = 3,202)	Mean salt iodine content (ppm)[b] (n= 415)	Median urinary iodine (μg/L) (n = 1,545)	Goiter prevalence (%) (n = 4,011)
Benin	10	1,116	97.9	58	293	1.2
Burkina Faso	10	1,001	97.8	48	114	22.4
Mali	9	901	94.2	60	151	13.4
Togo	10	993	83.7	39	116	4.3
Total	39	4,011	94.3	53	168	10.0

a. Presence of iodine determined by kits.
b. Iodine measured by titration.

Present status of iodine nutrition

Access to iodated salt and iodine content of salt at household level

Based on the results obtained from kits, the access to iodated salt at the household level in the four countries varied from 83.7% to 97.8%, with a global value of 94.3. It was above 90% in three of them.

Table 3 compares the iodine content of salt in the 415 salt samples in which it was estimated by both kits and titration. The results obtained by the two methods were markedly different. The kits overestimated both the absence and the elevated content of iodine. As a result, the percentage of salt samples meeting the legal requirements in the four countries of at least 50 ppm (see table 1) was about two-thirds (64.3%) according to the kits but only about one-third (36.3%) according to titration.

Moreover, the scatter of the results obtained by titration was important (table 3). Iodine was undetectable in 0.5% of the samples; its content was 1 to 14 ppm in another 17.3%, 15 to 49 ppm in 37.4%, 50 to 100 ppm in 36.3%, and above 100 ppm in the last 8.5%, including 0.5% in which it was above 200 ppm.

Urinary iodine concentrations

The median urinary iodine in the four countries derived from the 1,545 urine samples analyzed varied from 114 to 293 μg/L, with a global median value of 168 μg/L (table 2). As shown in table 4, the frequency distributions of urinary iodine were skewed toward high values. The frequency of values situated within the normal range (100–200 μg/L) [1] varied from 18.0% to 28.7% in the four countries, with a global frequency of 23.8%. For all samples taken together, 32.4% were below 100 μg/L, indicating iodine deficiency; 8% were below 20 μg/L, indicating severe iodine deficiency [1]; and 43.8% were above the upper limit of normal of 200 μg/L, including 24.9% above 300 μg/L.

TABLE 3. Comparison of the frequency distribution of the level of salt iodation obtained by using test kits or titration in 415 samples of table salt collected in the four countries

	Frequency distribution of level of salt iodation (%)		
Method	0 ppm	1–49 ppm	50–100 ppm
Test kit	1.9	35.7	64.3
Titration	0.5	54.7	36.3

Prevalence of goiter according to ultrasound

The prevalence of goiter in the four countries varied from 1.2% to 22.4%, with a global mean value of 10.0% (table 2). Figure 1 shows that there was only a poor relationship between the median urinary iodine and the prevalence of goiter in the 39 sites under investigation. With the exception of Benin, which was very homogeneous, with a median urinary iodine varying from 193 to 386 μg/L and a prevalence of goiter varying from 0% to 5.2%, i.e., within the normal range [1], the prevalence of goiter and the median urinary iodine varied markedly and almost independently of one another in spite of an almost identical access to iodated salt at the household level (table 2).

The prevalence of goiter in the four countries taken together increased with age (from 4.4% at 6 years to 12.5% at 12 years). Among the children with goiters, 60.6% were female and 39.4% were male.

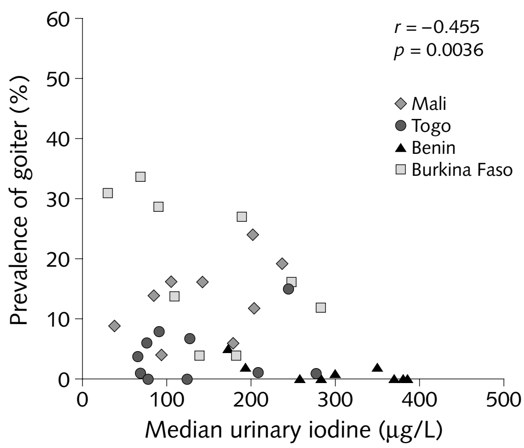

FIG. 1. Relationship between the prevalence of goiter and median urinary iodine in the 39 sites under investigation

TABLE 4. Frequency distribution of urinary iodine in the four countries

	Frequency distribution of urinary iodine concentration (%)[a]				
Country	< 20 μg/L	< 100 μg/L	100–200 μg/L	> 200 μg/L	> 300 μg/L
Benin	1.0	8.3	18.0	73.7	48.8
Burkina Faso	13.3	47.1	23.3	29.7	12.8
Mali	9.7	34.1	28.7	37.2	21.9
Togo	9.0	42.6	26.1	31.3	13.4
Total	8.0	32.4	23.8	43.8	24.9

a. 1 μg iodine/L = 0.787 μmol/L.

Normative values for thyroid volume in West African iodine-replete populations

The median urinary iodine concentrations among schoolchildren investigated in Cotonou and Lome were 370.0 and 124.6 µg/L, respectively, confirming iodine repletion. None of these children was goitrous.

Table 5 compares thyroid volume by age and sex obtained in the two coastal cities and the values obtained in iodine-replete populations in Europe [13, 19]. The values obtained in Africa were systematically lower than those obtained in Europe, both for medians (50th percentile) and upper limits of normal (97th percentile). Unfortunately, the results could not be expressed on the basis of body surface area, because data on weight and height were not systematically collected from these children.

Discussion

The ThyroMobil model has a very valuable role in assessing iodine nutrition. As underlined by Dunn [23], its great strengths are as follows:

» It provides standardized data on urinary iodine concentration and thyroid size. These data can be compared with international standards developed in populations with adequate iodine nutrition and also with the results obtained in other iodine-deficient populations.

» It provides publicity and consumer education by attracting attention from the community, the media, and politicians.

» Although it does not typically provide a comprehensive national survey, it does offer sufficient spot checking of communities to assess the current status of iodine nutrition.

The global outcome of the ThyroMobil model in the world has been summarized elsewhere [8]. So far, surveys conducted in Europe, Latin America, Indonesia, and West Africa have included 28 countries and 35,223 schoolchildren from 378 sites. The present work provides a detailed report of the African phase of the ThyroMobil model. It demonstrates unquestionable progress in the control of iodine-deficiency disorders in the four countries under investigation. There was a remarkable progress in the accessibility of iodated salt at the household level, which is presently close to 100%, a figure approximately 3 to 10 times higher than that reported for the same countries by WHO/UNICEF/ICCIDD less than three years ago (table 1)[6].

The median urinary iodine in the four countries is now in the recommended range of 100 to 200 µg/L, except in Benin, where it is slightly higher but still in a healthy range [1]. In parallel, the prevalence of goiter has markedly decreased as compared with the last evaluations (tables 1 and 2), although only two countries, Benin and Togo, have reached the recommended normal value of less than 5% [1]. The poor correlation between the prevalence of goiter and the median urinary iodine concentration probably indicates that, with the exception of Benin, which was the less severely affected and where the introduction of iodated salt occurred first (table 1), the countries have not yet reached their steady state in terms of iodine nutrition.

This illustrates once more that normalization of the prevalence of goiter takes much more time than normalization of urinary iodine [1, 24], and that a normal (above 90%)[1] level of access to iodated salt is not sufficient to guarantee that elimination of iodine-deficiency disorders has already occurred. The persistence of significant goiter rates in the presence of adequate iodine nutrition also suggests the additional role of

TABLE 5. Thyroid volume measured by ultrasound in boys and girls aged 6–12 years in iodine-sufficient coastal areas in Lome (Togo) and Cotonu (Benin) in the present study in comparison with the adapted [18] WHO/ICCIDD normative values [19]

	Boys				Girls			
	P50[a]		P97[b]		P50[a]		P97[b]	
Age (yr)	WHO/ ICCIDD adapted	Present study	WHO/ ICCIDD adapted	Present study	WHO/ ICCIDD adapted	Present study	WHO/ ICCIDD adapted	Present study
6	2.3	2.0	3.8	3.1	2.1	1.9	3.6	3.4
7	2.4	2.1	4.0	3.1	2.4	2.2	4.2	3.5
8	2.6	2.4	4.3	3.4	2.8	2.2	4.9	3.6
9	2.9	2.5	4.8	3.5	3.1	2.3	5.7	3.6
10	3.2	2.6	5.5	4.3	3.6	2.4	6.5	3.7
11	3.6	3.1	6.4	4.7	4.0	3.2	7.4	4.5
12	4.0	3.8	7.4	6.6	4.5	3.3	8.3	7.6

a. P50 indicates the median.
b. P97 indicates the 97th percentile.

naturally occurring goitrogens [25] or concomitant iron deficiency, which interferes with the utilization of dietary iodine [26]. These possibilities could not be explored during the present survey.

This work confirms that the test kits used for evaluation of the iodine content of salt have a low sensitivity and specificity, since they overestimate both the absence of iodine and high values of iodine in the salt [8, 27]. This work also shows an important heterogeneity of the iodine content of salt measured by titration, which at least partly explains a similar heterogeneity of the urinary iodine concentrations. As indicated earlier, in spite of the fact that more than 90% of households have access to iodated salt, only 23.8% of the urine samples are within the normal range. Of the samples, 40.4% were below 100 μg/L, indicating persisting iodine deficiency. However, 68.7% of the urine samples had a concentration above the upper limit of normal (200 μg/L), including 24.9% above the critical level of 300 μg/L, which is associated with a risk of side effects due to iodine excess [1, 28].

Finally, the thyroid volumes according to age and sex in 6- to 12-year-old schoolchildren from iodine-replete coastal cities in West Africa are all below the corresponding values established for European schoolchildren [13, 19]. Unfortunately, weight and height measurements could not be collected in the African children, so that a comparison with European normative values made on the basis of body surface area could not be made.

In conclusion, this work clearly demonstrates extremely encouraging progress toward the goal of sustainable elimination of iodine-deficiency disorders in West Africa. The results justify a reasonable optimism regarding the possibility of reaching the target in spite of the difficulties in implementing iodated-salt programs in this part of the world, especially given the multitude of small salt producers. However, this work demonstrates, as in most countries investigated by using the ThyroMobil model, that quality control of the iodine content of salt and monitoring of the iodine status of children must be markedly improved in order to reach the goal and to avoid the unfavorable side effects of sudden exposure to iodine excess in previously iodine-deficient populations [28].

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Relationship between waist circumference and blood pressure among the population in Baghdad, Iraq

Haifa Tawfeek

Abstract

We studied the relationship between waist circumference and hypertension among the Iraqi population in Baghdad. The study was carried out during 1999–2000. Body weight, height, waist circumference, and blood pressure were measured. According to multivariate analyses that included control for age and body mass index, waist circumference for men was positively and significantly correlated with systolic and diastolic blood pressure ($r = 0.31$ *for systolic pressure and* $r = 0.30$ *for diastolic pressure;* $p < .009$*). For women, the correlations were* $r=0.39$ *for systolic and* $r = 0.40$ *for diastolic pressure (*$p < .001$*). Intervention programs designed to reduce waist circumference may have significant public health significance in reducing the incidence of hypertension.*

Key words: Waist circumference, blood pressure, Iraq

Introduction

Overweight and obesity are associated with increased risk of a number of clinically important chronic conditions. These include type II diabetes, hypertension, hyperlipidemia, and coronary heart disease [1, 2]. Data from the Framingham offspring study suggest that the prevalence of risk factors for cardiovascular disease rises rapidly with a body mass index (BMI) greater than 20 kg/m^2 [3]. However, it is now clear that the risk also varies according to the distribution of body fat [4, 5]. Fat distribution is clinically important, since even people with average BMI can be at increased risk of cardiovascular disease if a high proportion of their body fat is abdominal [6]. Waist circumference is preferred to more complex indices of adiposity and relates strongly to health risks, because waist measurement reflects total and abdominal fat accumulation [7] and, as an index of adiposity, is not greatly influenced by height [8]. Hypertension is a common health problem in Iraq [9, 10]. Epidemiological studies have identified several personal attributes and factors associated with a higher prevalence of hypertension, such as obesity [11]. Yet, no local information is available about the importance of fat distribution as a predictor of hypertension. This paper examines the association between waist circumference and systolic and diastolic blood pressure among adults.

Materials and methods

Subjects

The subjects were selected from the staff and students of the University of Baghdad and the Technical Institute, as well as from those who attended primary health care centers in Baghdad.

The study design, project protocols, questionnaires, and procedures were approved by the Committee of Medical and Health Technology, Baghdad, and explained to the subjects. The study is a part of a study on hypertension and salt intake.* All those who satisfied the selection criteria agreed to participate in the study.

Between November 1999 and February 2000, a total of 1,500 subjects participated in the study. Subjects were eligible for inclusion in the study if they were apparently healthy, were nonsmokers, did not drink alcohol, were between 18 and 44 years old, and were not vegetarians. To ensure that the subjects satisfied the criteria for inclusion, they were given a detailed physical and medical examination by registered nurses or medical doctors.

The author is affiliated with the College of Medicine and Health Technology in Baghdad, Iraq.

* Tawfeek H, Ataia B, Nijeb Z. Relationship between dietary salt intake and hypertension among people in Baghdad, Iraq. Unpublished study, 2001.

Anthropometry

Body weight was measured to the nearest 0.1 kg with the subject wearing light clothes, and height was measured to the nearest 0.1 cm. Body mass index (BMI) was calculated as the weight in kilograms divided by the square of the height in meters. Waist circumference was measured to the nearest millimeter. Waist measurement cutoff points defined by Lean et al. [7] at action levels 1 and 2 were used.

Subjects were classified as overweight or obese according to World Health Organization (WHO) criteria [12]. Subjects with a BMI of 18.25 to 24.9 were classified as normal, those with a BMI of 25.0 to 29.9 as overweight, and those with a BMI of 30.0 or more as obese.

Blood pressure measurement

Blood pressure was measured under standard conditions. The subject was seated for at least five minutes, an appropriate sphygmomanometer cuff was applied to the right arm, and the blood pressure was measured using a standard mercury sphygmomanometer. Diastolic blood pressure was recorded at phase 5 (disappearance of Korotkoff's sound). The mean value of two measurements for all participants was taken. Hypertension was defined as a systolic blood pressure of at least 140 mm Hg and a diastolic blood pressure of at least 90 mm Hg. All measurements were made by the same trained investigators.

Data collection

Sociodemographic data (age, marital status, income, occupation, and educational level attained) were collected by trained interviewers. All of the interviewers had college degrees in nutrition and had participated in an intensive training program that included general interviewing techniques.

Data analyses

Data were statistically analyzed by SPSS (version 10.0) for windows.

All results are expressed as means ± SD. The chi-square and *t*-tests were used to compare the baseline data of selected subjects. Pearson's correlation coefficients were calculated to evaluate the strength of linear relationships between variables after adjustment for age and BMI. A p value less than .05 (two-tailed) was considered to indicate statistical significance.

Results

Of the 1,500 participants enrolled in the study, 700 (46.7%) were male and 800 (53.3%) were female. To evaluate a possible selection bias, background characteristics were compared for all subjects (table 1). Staff subjects were more educated and had a higher monthly income. The University and Technical Institute students were younger. Subjects who attended primary health care centers were less educated, and most of these were housewives with low monthly incomes.

The majority of the subjects were between 18 and 34 years of age. Only 2.7% of the men and 3.5% of the women were over 35 years of age. The mean age was 23.4 ± 15.8 years for men and 26.6 ± 16.3 years for women.

About half of the subjects (43.7% of men and 48.9% of women) had between 13 and 16 years of education. The monthly incomes were generally low, between 10,000 and 20,000 Iraqi Diners (US$1 = 2,000ID).

Table 2 shows the relationship between anthropometric indices and blood pressure. For men and women, respectively, the mean weight was 76.4 ± 13.3 and 67.5 ± 15.0 kg, the height was 165.4 ± 5.6 and 155.8 ± 16.1 cm, the body mass index was 28.0 ± 1.4 and 27.8 ± 6.3 kg/m^2, and the waist circumference was 87.3 ± 12.15 and 94.0 ± 13.3 cm. Women were shorter than men ($p < .05$) and had a greater waist circumfer-

TABLE 1. Characteristics of the subjects

Variable	Men (N = 700)	Women (N= 800)
	no. (%)	
Group		
University and technical staff	91 (13)	91 (11.4)
University students	340 (48.6)	331 (41.4)
Technical students	269 (38.4)	272 (34.0)
Primary health care center attendees	—	106 (13.2)
Age range (yr)[a]		
18–24	351 (50.1)	372 (46.5)
25–34	309 (44.2)	375 (46.9)
35–44	40 (5.7)	53 (6.6)
Education (yr)		
< 6	—	11 (1.4)
6–12	—	45 (5.6)
13–16	659 (94.1)	734 (91.8)
> 16	41 (5.9)	10 (1.2)
Monthly income (ID)[b]		
< 10,000	81 (11.6)	102 (12.8)
10,000–20,000	573 (81.9)	613 (76.6)
> 20,000	46 (6.5)	85 (10.6)
Occupation		
Housewife	—	68 (8.5)
Student	609 (87)	603 (75.4)
Staff	91 (13)	91 (11.4)
Other	—	38 (4.7)

a. Mean age: 23.4 ± 15.8 years for men and 26.6 ± 16.3 years for women.
b. US$1 = 2,000 ID.

ence ($p < .01$). In contrast, the mean BMI was higher in men, 14.5% of whom met the BMI criterion for obesity (30.0), whereas 12.6% of females did so.

The overall prevalence of hypertension was 10.6% in men, as compared to 13.4% in females. The difference in the prevalence was not statistically significant.

The relationship between blood pressure and waist circumference is shown in table 3. About 13.3% of men and 22.5% of women who had a waist circumference equal to or higher than action level 2 (94 cm for men and 80 cm for women) were hypertensive (blood pressure of at least 140/90 mm Hg).

The association between blood pressure and anthropometric indices (weight, height, and waist circumference) is shown in table 4. After adjustment for age and BMI, waist circumference was correlated significantly and positively with blood pressure; among men, $r = 0.31$ for systolic pressure and $r = 0.30$ for diastolic pressure; among women, $r = 0.39$ for systolic pressure and $r = 0.40$ for diastolic pressure.

Discussion

This study supports an earlier finding that waist circumference identifies people with high metabolic function [6]. Several considerations need to be taken into account in the interpretation of our results. Random sampling with selected criteria was designed for this study in order to avoid bias error; however, sampling bias is a possible source of error because of the relatively small number of observations of women who attended primary health centers.

Furthermore, from the data on monthly income, level of education, and occupation, it appeared that the mean socioeconomic status of the staff subjects was slightly above the mean of those in other studies. This was further confirmed by the fact that a high proportion of these subjects had a BMI of 25 or more, whereas only 19% of university and technical students and 15% of women attending primary health care centers had such a BMI.

However, after data from all subjects with high socioeconomic status had been eliminated, the positive association between waist circumference and hypertension persisted (data not shown).

Inadequate control for physical activity may also have biased the results and could affect the relation between the distribution of body fat and hypertension. However, occupation may be related to hypertension. Because the majority of the subjects had similar activity patterns (staff, students, and housewives), it is unlikely that the associations reported in table 3 are biased by physical activity patterns.

A major obstacle in studies of the distribution of body fat is the choice of the most appropriate indicator. Measurement of a central pattern of body fat is susceptible to error. Despite considerable attention paid to the reliability of the measurement, misclassification resulting from measurement error may have resulted in an underestimation of the real associations. In studies of a central pattern of body fat, advanced methods such as computerized tomography are more reliable, but because of their high cost they will not be available soon for epidemiologic studies [13, 14]. Currently, the use of waist circumference is preferred [6]. Recognizing the ease of measurement, we used waist circumference with cutoffs derived from a large population study [6, 7].

TABLE 2. Anthropometric indices and blood pressure values[a]

Variable	Men ($n = 700$)	Women ($n = 800$)
Weight (kg)	76.4 ± 13.3	67.5 ± 15.0
Height (cm)	165.4 ± 5.6	155.8 ± 16.0
Body mass index (kg/m^2)	28.0 ± 1.4	127.8 ± 6.3
18.0–24.9	152 (21.7)	241 (30.1)
25.0–29.9	330 (47.1)	370 (46.3)
≥30.0	218 (31.1)	189 (23.6)
Waist circumference (cm)	87.3 ± 12.15	94.0 ± 13.3
Blood pressure (mm Hg)		
Systolic ≥ 140	240 (34.3)	118 (14.8)
Diastolic ≥ 90	215 (30.7)	180 (22.5)
Systolic ≥140 and diastolic ≥90	159 (22.7)	201 (25.1)

a. Values in parentheses are percentages.

TABLE 3. Relationship between mean blood pressure and waist circumference (percentage of subjects)

Sex and waist circumference (cm)	Blood pressure (mm Hg)		
	Systolic ≥140, diastolic ≥90	Systolic ≥140	Diastolic ≥90
Male ≥94	13.3	16.6	15.0
Female ≥80	22.5	41.5	32.5

TABLE 4. Correlation coefficients between anthropometric measurements (adjusted for age and BMI) and systolic and diastolic blood pressure

Subjects	Correlation coefficient		
	Weight	Height	Waist
Men			
Systolic	0.03	0.08	0.31
Diastolic	0.19	0.06	0.30
Women			
Systolic	0.25	0.17	0.39
Diastolic	0.45	0.22	0.40

Individual circumference measures, rather than waist-to-hip ratios, have less measurement error and may be more practical for weight guidelines [15]. The lack of dietary intake data from the subjects could affect the external validity of the study design. For most Iraqi families, the type and amount of food have been limited to that distributed according to the government rationing system since 1990. All additional nutritional needs must be provided at market prices, which are the beyond the means of most families [16].

Although food is readily available in markets, the purchasing power of the average Iraqi has declined. The majority of the subjects (79.1%) had an income of 10,000 to 20,000 ID per month. Only the staff subjects had high monthly incomes and were able to supplement the ration from the market. As discussed above, data from all subjects of high socioeconomic status were removed from the analysis of the association between waist circumference and hypertension.

On other hand, efforts to ensure standardized measurements tend to minimize the errors. The age range of the subjects, as well as risky behaviors, such as smoking, use of medications, alcohol, and stress, were well controlled at enrollment. Except for the women attending primary health care centers, all subjects were from the same environment and were subsequently exposed to the same level of anxiety and stress.

Both systolic and diastolic blood pressure were positively associated with waist circumference after age and other potential risk factors had been controlled for. These results agree with those of Okosun et al. [17], in that waist circumference was positively correlated with blood pressure. Waist circumference has been shown to be a better correlate of blood pressure than waist-to-hip ratio [18]. In contrast, Cox et al. [19] found weak evidence for an association between waist circumference and hypertension.

In an often-cited hypothesis concerning the mechanism relating a central pattern of body fat to blood pressure or lipoproteins, hypertrophied intraabdominal adiposity plays a key role [20]. Visceral fat is more metabolically active and thus increases hepatic exposure to free fatty acids and decreases insulin sensitivity. Because free fatty acids may inhibit the uptake of insulin by the liver and stimulate the production of triglyceride-rich very-low-density lipoprotein and other adverse lipid conditions, visceral fat may be associated with hypertension, hypertriglyceridemia, diabetes, and coronary heart disease [21, 22].

Pouliot et al. [4] observed exponential increases in cardiovascular risk with a waist circumference of 87 cm in men and 78 cm in women (which correspond to waist circumference of action level 1), and further increases in risk with waist circumferences around those of action level 2.

Our results suggest that action levels based on waist circumference measurement may provide a valuable, simple method of alerting people at increased risk of hypertension. Under the very special circumstances of Iraq, nutritional control of overweight and obesity is urgent, especially in those over 40 years of age with sedentary lifestyles.

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Chronic poisoning by hydrogen cyanide in cassava and its prevention in Africa and Latin America

Francisco Franco Feitosa Teles

Editorial introduction

*Because of the importance of cassava (*Manihot esculenta *Crantz) as a food crop for Africa and parts of Latin America, the* Bulletin *has occasionally accepted articles dealing with this subject. The* Bulletin *last published an article on this topic in 1992 [1]. The issues remain the same: the almost negligible protein value of cassava and issues relating to its cyanide content. The former means that diets that depend on cassava as a major energy source must be supplemented by animal or legume protein to avoid serious malnutrition. The latter means that consumers must correctly use time-honored traditional methods of detoxification and distinguish between bitter varieties that are high in cyanide and "sweet varieties" that require less drastic and prolonged treatment to be safe for human consumption. The review article that follows breaks no new ground, but it serves as a reminder once again of both the dangers and the nutritional importance of cassava cultivation and consumption in tropical regions. As to the toxicity, new and safer varieties developed through plant breeding and the application of biotechnology could make an important contribution. However, this cannot be a substitute for access to quality protein sources to supplement a cassava-based diet.*

Editor

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Abstract

Africa produces more than 30 million tons of cassava on about 5 million hectares (6 tons per hectare). Approximately 80% of the root production and 70% of the harvested area are from Western Africa. Recent reports suggest that the ingestion of poorly processed cassava roots is associated with the incidence of an ataxic neuropathy (konzo) in African countries. When cassava-based diets are not supplemented with good sources of protein and iodine, goiter and rickets are also prevalent. In certain countries of Africa where the rate of ataxic neuropathy is high, the incidence of thyroid disorders is also high. Persons consuming poorly processed cassava in large quantities are susceptible to neuropathologies caused by cyanide. Cyanide detoxification in the body is impaired by protein deficiency. When properly processed, the root of cassava is safe and cheap as a major dietary energy source for humans and domestic animals; however, a cassava-based diet will lack sufficient protein and will be particularly deficient for the growth and development of children unless it is supplemented by protein from animal, including fish, or legume sources. Cassava leaves, if they are appropriately cooked, can be a useful source of some nutrients.

Key words: Cassava, HCN intoxication, Africa, Latin America

The author is a Professor of Nutritional Biochemistry at the Universidade Estadual Vale do Acaraú (UVA) in Sobral-CE, Brazil.

Cassava in the human diet

Cassava (*Manihot esculenta* Crantz) belongs to the Euphorbiaceae family and is a native of South America, probably from the Brazilian Northeast. Long before the Columbian discovery, it was used by Native Americans, who considered it mystical or even divine. In the sixteenth century, the Portuguese took it to Cabo Verde, from which it spread throughout West Africa. Following the commerce of ivory and slaves, cassava reached all the African continent and part of Asia.

Cassava is now the staple food of more than 500 million people [1] in Latin America and Africa. Among the low-income African population, it provides more than 40% of the calories for more than 200 million people. This rapid spread of cassava cultivation was due to its ease of cultivation and low cost of production. It grows on poor and poorly prepared soils, it can stand severe drought and insect attacks, and the roots can remain underground for months without decomposition, even after its leaves have fallen. Some varieties, such as the *manipeba preta*, allow harvesting more than five years after planting.

Its productivity depends only upon the care devoted to it. In family cultivation during low rainfall, cassava production is 3 to 15 tons per hectare, whereas in well-conducted industrial plantations production can reach 100 tons per hectare. Cassava is also an important source of raw material for the industries of starch, alcohol, glucose, acetone, glues, paper, stabilizers, etc.

Nutritive value

Both the tuberous roots and the leaves are used as food for human consumption. Although the leaves are rich in crude protein, they are very poor in methionine, an amino acid that is not only essential but also important in cyanide detoxification. One-third of the root is starch, 60% to 70% is water, and 5% to 10% is bark, peel, and fibrous central cord. Cassava roots are rich in nonstructural digestible carbohydrates [2] but very poor in protein and essential amino acids. Therefore, although cassava is an important and cheap source of dietary energy for poor populations in tropical areas, it must be complemented by a good protein source.

Toxicological aspects

Cassava contains four or five cyanogenic glycosides. The most prevalent are linamarin and lothaustralin, which usually occur at a ratio of approximately 1:1. These glycosides are found in all parts of the plant, but the leaves are more toxic than the roots. Their content varies according to the age of the plant, the variety, environmental conditions, type of soil, climate, cultural tracts, etc.

In 1897 Theodore Peckolt discovered that cassava has no free hydrocyanic acid (HCN) when intact. The presence of this acid is due to tissue breakdown [3–5]. Thus the determination of "free cyanide" (CN) in cassava roots, a tedious and expensive process, tells only the degree to which the root has been broken down.

The free HCN never occurs during the synthesis of the cyanogenic glycosides. Figure 1 presents the principal metabolic pathway for the synthesis of the principal cyanogenic glycosides found in cassava [5]. Acid, enzymatic, or thermal hydrolysis results in the production of HCN, one or two sugar molecules, and one aldehyde or ketone.

The principal toxic component of cassava is HCN, although it contains other toxic substances, such as alkaloids and toxic proteins. Intoxication by ingestion of cyanogenic glycosides begins in the first steps of digestion, consisting of acid hydrolysis, followed by enzymatic hydrolysis by the microflora.

Young leaves contain the most HCN, around 600 mg/kg of fresh material. The level is much lower in the roots, especially in domesticated or sweet varieties. In the roots, the HCN concentration is higher in the central cord and in the bark. Analysis using alkaline picrate reveals the formation of two concentric toxic rings, one around the cord and another in the intersection between the bark and the core. The core (without bark and central cord) contains between 20 and 50 mg of HCN per kilogram of fresh matter.

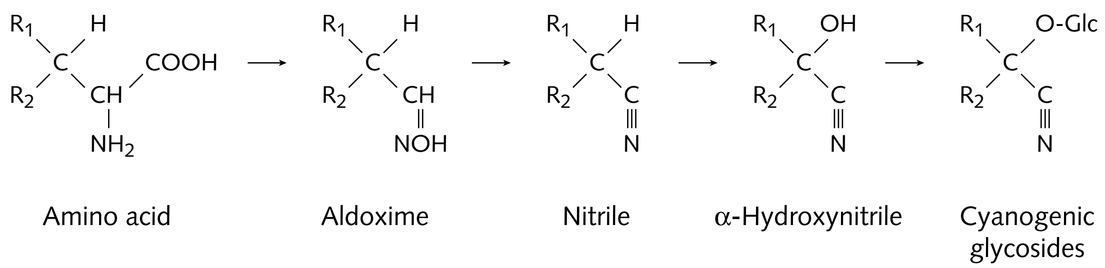

FIG. 1. Biosynthesis of cyanogenic glycosides from a precursor amino acid [5]

Metabolism and toxicity

For linamarin, $R_1 = R_2 = CH_3$, and the amino acid is valine. For lothaustralin, $R_1 = C_2H_5$, $R_2 = CH_3$, and the amino acid is isoleucine. For prunasin, R_1 = phenyl, R_2 = H, and the amino acid is phenylalanine. For durhin, R_1 = p-hydroxyphenyl, R_2 = H, and the amino acid is tyrosine. The metabolism of linamarin is not very well known. Biochemically the catabolism must initiate with the enzymatic decomposition of the glycoside, as shown in figure 2.

Even less known is the process of excretion of the intact glycoside, although some experiments in rats have demonstrated the presence of minute quantities of those toxins in the urine. However, this is not enough to account for the transport and renal clearance of these relatively large compounds.

Apparently, the main pathway in humans in response to cyanogenic glycosides intoxication is the sulfuration of the cyanide radical (-CN) with sulfur provided by sulfur-containing amino acids, such as cysteine and methionine, in a general reaction as follows:

(1) Glycoside-CN + S-amino acid → aminothyazol → urine,

or

(2) Glycoside-CN → HCN + S-amino acid → SCN → saliva and urine

In the first reaction, if the amino acid is cysteine and the glycoside is linamarin, the final product to be excreted in the urine is the acid 2-aminothyazol-4-carboxylic. In the second case, the amino acid could also be methionine, and the product excreted in the saliva or urine is NaSCN (sodium thiocyanate) [6].

Acute intoxication

The cause of acute intoxication from cassava is HCN, one of the most powerful poisons for human beings. It is a liquid that boils at 25.7°C. When very diluted in air, its odor resembles that of bitter almonds, very similar to that of hot cassava broth. The inhalation of only 2 mmol is enough to kill a 70-kg man. Moreover, the cyanide ion is very reactive and combines rapidly with metallic ions to form toxic complexes [7]. Fortunately, acute intoxication by HCN derived from cassava is rarely reported. However, in 1990 in Horizonte, State of Ceará, Brazil, an entire family of eight persons was acutely intoxicated after ingesting bitter cassava roots. Four children died, and the adults were hospitalized for many days.

The police confirmed that the family had stolen the roots from a neighbor's cassava plantation, assuming that they were the much less toxic sweet variety. Instead, they ate a very toxic variety, after very inadequate cooking, because in time of drought in the semiarid lands of Northeast Brazil there is a lack not only of water but also of fuel for cooking. Except for this single outbreak in Brazil, there has been no report of acute intoxication by cassava ingestion in Latin America. This is due in part to the fact that Brazil is the only country in Latin America that cultivates the very toxic varieties on a large scale. The other Latin American countries produce mainly sweet varieties for consumption after cooking.

Africa produces more than 30 million tons of cassava on about 5 million hectares (6 tons per hectare). Approximately 80% of the root production and 70% of the harvested area are in tropical Western Africa [8]. However, very rare cases of acute intoxication produced by cassava root consumption have been reported, usually only by personal communication. Even when the intoxication is lethal, the cause is likely to be masked by other symptoms usually related to nutritional diseases, particularly undernourishment, marasmus, and kwashiorkor. The International Center for Tropical Agriculture (CIAT) in Ibadan, Nigeria, has a program to analyze all the varieties in its large bank of germplasm in search of cultivars with zero or very low levels of cyanide. However, it is not working on methods of detoxification [9].

Chronic intoxication

The existence of chronic intoxication by cyanogenic glycosides was suspected for a long time because of the large consumption of cassava roots in Africa and

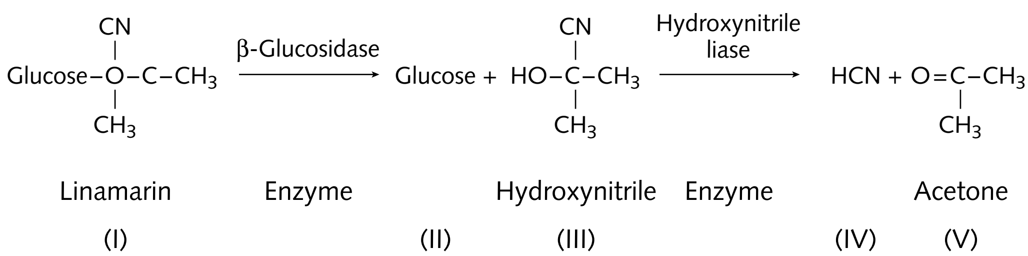

FIG. 2. Metabolism of linamarin

Latin America. However, the initial alert for this was an interdisciplinary workshop held in London under the auspices of the International Development Research Center (IDRC) in January 1973 [10].

It was evident at this meeting that the ingestion of large quantities of poorly processed cassava roots is associated with ataxic neuropathy in African countries. This syndrome is usually associated with diets very poor in iodine and protein and the appearance of rickets. In certain countries of Africa, where the rate of ataxic neuropathy is high, thyroid disorders are endemic [10]. Persons consuming poorly processed cassava in large quantities and a low-protein or poor-protein diet are prone to develop neuropathologies caused by cyanide, particularly because their mechanism for cyanide detoxification is impaired by the deficiency of sulfur-containing amino acids.

Six pathological states are recognized in chronic cyanide intoxication:

» Exacerbation of protein deficiency because of a low intake of methionine and cysteine that are used for the detoxification of the HCN [11].
» Populations with a large consumption of cassava roots are susceptible to goiter and rickets. This is due to the low iodine in the diet and the presence of thiocyanate (SCN-) in the blood, an inhibitor of the thyroid hormone synthesis [12, 13].
» Tropical neuropathy is the name given to neurologic degenerative diseases found only in tropical areas where there is a large consumption of cassava [14].
» Diabetes associated with calcification of the pancreas has been observed [15].
» Cancer caused by the formation of carcinogenic nitrosamines in the stomach. This reaction is induced by SCN- excreted in the saliva and gastric juice [16].
» Congenital malconformation: an abnormally high incidence of imperfection of the limbs was demonstrated in rats [17].
» Konzo, an epidemic disease from a nonprogressive spastic paraparesis, reported in rural areas of sub-Saharan Africa, is associated with large consumption of cassava roots [7].

Cases and causes of acute and chronic intoxication among cassava consumers

As noted earlier, cases of acute lethal intoxication among cassava-consuming populations are very rare and could be considered as due to accidental circumstances. In order to be acutely intoxicated, one must eat a very toxic variety and neglect all the traditional techniques used in the preparation of the food. These techniques ensure detoxification of the roots and leaves. Children seem to be more susceptible to cyanide intoxication. This kind of intoxication is not usually reported, because the majority of cassava consumers are located in rural areas where facilities for diagnosing and reporting the disease are almost nonexistent.

Casadei [1] considers that cyanide intoxication by cassava roots happens only in cases of recent introduction of a very toxic variety in a rural area or city where it was not known before or a great shortage of food and utilization of products that have not been detoxified. Such were the cases cited in Brazil and the well-known case in Mozambique, where in a six-year period the National Health Laboratory registered four child deaths in the city of Maputo, and five adults died in other Mozambican cities [18]

Cases of chronic intoxication are being increasingly well documented. The tropical neuropathies associated with large consumption of cassava with peripheral ataxia were studied in Nigeria and Tanzania. In 1981, after a long period of drought in northeastern Mozambique, cassava was the only food available. The highly toxic character of the local cultivated varieties and the limited detoxification carried out by the local people resulted in an epidemic of high levels of SCN- in the blood and severe cases of spastic paraparesis associated with the chronic intoxication produced by cyanide ingestion [19]. With more than 500,000 people living in the area, over 1,100 cases of acute spastic paraparesis were observed over six months. The urinary concentration of SCN- in the population increased during the cassava harvest and decreased when the weather conditions improved [1]. Further information is provided in the well-documented book *The causation of konzo* [7].

Cassava detoxification

The techniques commonly used for HCN liberation to detoxify cassava roots and leaves have been described elsewhere [20]. The origins of the techniques are lost in prehistory. They vary with country and continent and among regions of the same country. The techniques and processes generally used involve sun-drying, grinding and grating, pressing, immersion in water, fermentation, roasting or cooking, or usually a combination of these. In these processes the glycosides are eliminated by hydrolysis, freeing the very volatile HCN to be lost in the surrounding atmosphere.

Sun-drying is the most common technique used in Africa and Latin America. It is cheap and simple, and allows the preservation of cassava for a time of crisis or commercialization. The roots, either peeled or not peeled, are cut in slices or longitudinally and dried in the sun, while the mass is revolved occasionally for 2 to 4 days, depending upon the weather conditions. In Brazil the roots are sliced in a machine developed specifically for this purpose, and the slices are dried in a yard made of concrete or bricks. If it is ground, the product is called *farinha de raspas secas ao sol* (flour from sun-dried slices). The process of sun drying-reduces 60% to 70% of the HCN in the first two months of preservation. However, the residual HCN is very high, reaching levels of 30 to 100 mg/kg.

Grinding and grating the fresh product breaks down the plant tissue, promoting biochemical reactions between the glycosides and endogenous and exogenous enzymes. Detoxification depends on the length of time the sample rests, temperature, particle size, and pH (which should always be over 5). In Latin America the grated product is usually pressed and baked as a cake (*beiju*) or roasted as *farinha de mesa* (cassava flour).

Immersion in water is ineffective when the soaking time is too short. After 4 hours of immersion, only 5% of the HCN is liberated. After 20 hours, the HCN level is reduced to about 50%. In this case, the immersion helps in the process of detoxification, because it breaks the cells by osmosis and some fermentative action, which contributes to glycoside hydrolysis. In the Brazilian Northeast, the product is immersed from 2 to 8 days and then grated, pressed by hand into small cakes, and sun-dried. This product is called *carimã* and has very good palatability and digestibility. It is a safe energy source even for small children and the elderly, because the residual level of HCN is very low. In another process, after immersion for 4 days, the roots are grated or ground, pressed, and finally roasted to produce *farinha d'água* (water flour). This product is completely safe.

Pressing of the grated or ground product is the fundamental step in detoxification. Because the glycosides and cyanides are soluble in water, they are eliminated together with the cassava sap (*manipueira*). Flour derived from a well-pressed mass has HCN levels up to 30% lower than those of a poorly pressed mass. Thus, fermentation under water, followed by pressing and sun or oven-drying, is the most effective method of detoxifying cassava roots.

Cassava leaves can provide a small but significant amount of good-quality protein and iron, as well as carotenoid precursors of vitamin A. However, the sun- or oven-dried leaves are always toxic and should not be used for human consumption. The detoxification of the leaves is generally accomplished by an exhaustive (3–4 days) cooking period, combined with different spices and herbs in a soup called *maniçoba.* This product is commonly consumed in the Brazilian Amazon. Cooked cassava leaves are an important dietary component in many other tropical regions.

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Participation in labor-intensive public works program (LIPWP): Effect on staple crop production in southeastern Botswana

Kesitegile S. M. Gobotswang, Geoffry C. Marks, and Peter O'Rourke

Abstract

A labor-intensive public works program (LIPWP) aims to improve the income of rural households. One of the common criticisms of the LIPWP is that it is a disincentive for staple crop production. This study, conducted between February and May 2000, examined the association between participation in an LIPWP and staple crop production in southeastern Botswana. Participant households were those with at least one member on a semipermanent LIPWP. A control group was drawn from households that were eligible to participate in the LIPWP. All participants in the LIPWP were included, while non-participant households were randomly selected. A structured questionnaire was administered to 160 control and 153 participant households. The odds of having no staple crop in the control group were 1.8 times (95% CI, 0.98 to 3.54) higher than that of the LIPWP participants ($p = .087$)*, while the odds of having no staple crop in a household with a head between 45 and 64 years of age were 2.5 times (95% CI, 1.06 to 5.96) higher than that of a household with a head less than 45 years old* ($p < .037$)*. Having more than 10 livestock equivalent units reduced the risk of having no harvest by 40% (95% CI, 0.29 to 1.12). The view that participation in the LIPWP results in reduced staple crop production does not seem to be supported by our data.*

Key words: Public works participation, household food security, staple crop production, livestock asset, Botswana, Africa

Kesitegile S. M. Gobotswang is affiliated with the Department of Home Economics, University of Botswana, in Gaborone, Botswana. Geoffry C. Marks and Peter O'Rourke are affiliated with the School of Population Health, University of Queensland, in Queensland, Australia.

Introduction

When Botswana attained independence in 1966, agriculture contributed 40% to the gross domestic product (GDP) and about 90% of total employment opportunities [1]. This percentage has since declined to 4% of GDP [2], due in part to rapid growth of the mining sector and poor crop yield [1]. The poor performance of agriculture is partly attributable to adverse weather conditions and poor soils. In good years (e.g., 1987–88), 60,000 metric tons of grain was produced, out of an annual cereal requirement of 200,000 metric tons [3]. The highest post-independence grain production recorded was 121,700 metric tons in 1976–77. Over the years Botswana has remained a net importer of food grains. The local market is well developed, ensuring adequate food distribution, even to remote places [4]. Despite the adverse conditions, subsistence agriculture is the single most common productive activity for rural households [5].

A labor-intensive public works program (LIPWP) is one of the strategies employed to address problems of rural income, poverty, nutrition, and unemployment. In semiarid, drought-prone countries, the program is also used to minimize the negative effects of drought [2, 3]. The program is designed to provide basic rural social and physical infrastructure [6]. Payment is made either in cash or in kind, depending on the level of development of the local market [4].

One of the common criticisms of the LIPWP is that it acts as a disincentive for staple crop production, which may result in a poor nutritional status of members of participant households, especially preschool children [7, 8]. As cash wages increase, nutrition is affected, because women lose control of a vital resource, resulting in increased expenditure on nonfood commodities [9]. In Botswana the daily wage for people working on LIPWP increased from P5.50 (US$2.70) in 1991 to a statutory minimum wage for the private sector of P12.70 (US$2.85) in 1998 [10]. To date there is limited information on the effects of LIPWP on staple crop production.

This study examined whether there is an association between participation in the LIPWP and staple crop production in Kgatleng District, Botswana. The household is used as a unit of analysis, because the LIPWP targets households. For the purposes of this study, a household is defined as persons comprising a single economic unit plus anyone visiting for at least 15 days during the survey month [11]. The reported data are a component of a larger survey that looked into participation in the LIPWP and its impact on staple crop production, household assets, and income. The project was supported by a collaborative arrangement between the Research and Development Unit (formerly the National Institute of Development Research and Documentation [NIR]), the University of Botswana, and the Institute of General Practice and Community Medicine (IASAM), University of Oslo, Norway.

Materials and methods

A survey was carried out between February and May 2000. Specifically, a post-test only with a comparison group was employed [12]. The reference period was the 1998–99 crop season, which had experienced drought. In Botswana farmers produce only one crop a year.

The study compared households participating in a semipermanent LIPWP with those that did not participate in any public works program but that demonstrated a willingness to partake in the LIPWP. Willingness to participate in the LIPWP was determined by identifying a household that had at least one member who took part in a temporary labor-based drought relief program (LBDRP) implemented between July 1999 and June 2000. The ideal study design would require collecting baseline data prior to participation and conducting a post-test after a specified time period. Because the LIPWP had been in existence for 20 years, it was not possible to adopt such a study design. Finding an equivalent comparison group was not easy either. We needed two groups that were comparable, the only difference being participation in the LIPWP. The two study populations were expected to share some similarities. Both the LIPWP and the LBDRP are treated as social welfare programs and are not covered by existing labor laws. They tend to attract mainly women, in part because the tasks performed are strenuous and rather menial.

Description of programs

The LIPWP scheme aims to alleviate income poverty by providing long-term employment to poor rural people. In the short to medium term, it is intended to increase household income and improve the nutritional status of members of participating households.

Part of the reason the program is called labor intensive is that 78% of the total expenditure goes to participants. The task, which mainly involves maintenance of dirt roads, is physical and strenuous. Each participant is allocated a kilometer of road to work on each day and is expected to cover 100 m per day to reshape the carriageway or 50 m to patch potholes. The participants normally start as early as 5 a.m. and work until the tasks are completed, usually within eight hours [6]. An LIPWP project is terminated when a dirt access road is upgraded to gravel as maintenance switches to the use of machinery. Hence, we describe it as semipermanent. To attract low-income households, LIPWP wages are usually set below the statutory minimum rate.

When there is a severe crop failure because of below-normal annual rainfall, the country can officially be declared drought stricken. After the 1998–99 crop failure, Botswana was declared drought stricken. To minimize the negative effect of drought, a variety of drought relief assistance programs are introduced, including the LBDRP. The drought relief measures are usually implemented until the next harvest. The daily wage for the LBDRP is set at P8.00, which is lower than the LIPWP rate. Because LBDRP cannot absorb everyone who is willing to participate, jobs are shared among the beneficiaries, each working for at least one month. During the long drought years of the 1980s, people participated for an average of 76 days per year [5]. To avoid competing with agricultural activities, the LBDRP is stopped during the cultivation season. Therefore, the LBDRP is not expected to have any impact on staple food production. During the cropping season of reference (1998–99), the LBDRP was not implemented.

Study area

The study was conducted in Kgatleng District. The area was purposely selected because it had one of the highest levels of LIPWP activities. In addition, Kgatleng District has several features that characterize most rural districts in Botswana. The residents are predominantly subsistence farmers. The area was convenient for a limited budget because of its small size. Further, Kgatleng is close to the city of Gaborone, where this researcher (KG) and the necessary research infrastructure were based.

Villages with at least 10 participants were considered eligible for the study. Altogether seven villages were actively involved in the LIPWP in Kgatleng, but only five villages were covered during the study. One village was excluded because it was used for the pilot test, while another was excluded because the majority of participants in the LIPWP were not residents of Kgatleng.

Determination of sample size

Because data were lacking to estimate the expected changes in key outcome variables resulting from participation in the LIPWP, we used available information from studies that examined the effect of small-scale agricultural commercialization on agricultural production, income, and food consumption. To observe a change (⅓ of the standard deviation) in crop production at a 5% level of significance and a power of 80%, a sample size of 284 households with 142 in each study group was required. To allow for a 10% nonresponse rate and given available resources, we aimed to cover 312 households, with 156 in each study group.

All of the 167 individual LIPWP participants were included in the study. To select a control group, a simple random sample proportional to the size of the study population was employed. To accomplish this, a sampling frame was constructed from the November–December 1999 LBDRP monthly payment forms obtained from Kgatleng District Council Revenue Offices.

Once the individual participants and controls were selected, the enumerators contacted their households to consult with the heads of the households to seek their consent for participation in the study and to administer a household questionnaire.

Data collection and analysis

Data were collected on sociodemographic characteristics of the population groups. Information on cropping activities was obtained (based on recall) during face-to-face interviews. This included information on access to land, the amount of land available, whether it was cultivated during the previous season, the area cultivated, and the staple crop harvested. In addition, information on livestock asset ownership was also collected. Livestock ownership was converted into livestock equivalent units (LSEUs), with 1 cow, 3 donkeys, or 6 goats or sheep equivalent to 1 LSEU [13, 14]. The main staple crops considered in this study were sorghum, millet, maize, and pulses. Each crop produced was measured in 70-kg bags. These were aggregated to arrive at one staple crop measure per household.

We used SPSS (Version 10) for data analysis. In order to apply logistic regression analysis, the amount of household staple crop produced was recoded as a binary variable. Households that received at least one bag (70 kg) of staple crop were recoded as having obtained "some harvest," and the rest fell into a "no harvest" category. The chi-squared test was used to test for associations between variables, and testing between means was done by Student's *t*-test. The test for significance was at the 5% level. Independent variables that were significantly associated with the dependent variable during the univariate analysis were modeled by using stepwise backward logistic regression modeling techniques. The aim was to determine important explanatory variables for the outcome variable of staple crop produced. The sex, age, marital status, and educational status of the head of the household, the household size, and livestock ownership were included in the original model.

Staple crop production conceptual framework

Two criteria were used in considering variables for inclusion in the model. Independent variables that were found to be important from the univariate analysis were eligible for inclusion; others were included because of the interest generated by the literature and policy. These variables were participation in the LIPWP; age, sex, educational status, and marital status of the head of the household; livestock ownership; place of residence; and size of the household.

Because participation in the LIPWP (STUDYGR) was central to this study, the variable was included in the model in order to assess its effect on staple crop production. During the initial analysis, participation in the LIPWP had no effect on staple crop production.

Livestock assets (expressed as LSEUCAT) are included in the model, because livestock, especially cattle and donkeys, provide draft power that is required to cultivate land for crop production [4]. From the univariate analyses, we found that livestock ownership was associated with crop production. Households participating in the LIPWP tended to have more productive resources than controls [6].

The sex of the head of the household (SEXHD) is included because it is generally expected that the level of resources necessary for crop production is influenced by sex, and women are less likely than men to own cattle in Botswana [6]. Further, poverty affects female-headed households more than male-headed households [5]. Correcting gender inequality is currently central to public policy in Botswana [2]. Education (EDUCAT) is associated with better living standards through increased job opportunities, because it empowers individuals to make informed economic decisions.

Like the sex of the head of the household, the marital status (MARITGR) and age (HAGEGR) of the head of the household are generally associated with better resources. A household with a married head is more likely to have a larger asset base [11]. Another variable that is included is place of residence (RESIDENCE). We hypothesized that because members of participant households tended to reside in "other places," whereas members of control households lived in villages, there would be a difference in staple crop production between the different localities. "Other places" include lands and cattle post areas where crop production and livestock rearing take place. Household size (HSIZEGRP) is used as a proxy measure for the labor required to produce a staple crop. This is judged to be important, because control households were significantly larger than participant households. On the other hand, female-headed households were larger than male-headed households [11]. Figure 1 presents a conceptual framework for analyzing the effect of participation in LIPWP on staple crop production.

Based on the hypotheses listed above, the following model specification is presented: STAPLE CROP PRODUCED = f(STUDYGR, HAGEGR, SEXHD, EDUCAT, MARITGR, LSEUCAT, RESIDENCE, HSIZEGRP).

Results

Sociodemographic information

A total of 153 households participating in the LIPWP and 160 controls were interviewed. The average age of the head of the household was 54 ± 14.93 years in participating households and 55 ± 15.7 years in nonparticipating households (table 1). Nonparticipating households were significantly larger than participating households (7 ± 3.37 vs. 5 ± 3.24; p =.000).

Data on sex distribution showed that 48.2% of households were headed by women. Nationally, 47% of households are headed by women, and these constitute a large percentage of people living below the poverty datum line (PDL) in Botswana [15]. Nonparticipating households had a larger proportion of female-headed households than participating households. There was no difference between the two study populations in the marital and educational status of the heads of households. About 55% of heads of households had no education, and 30% were married.

TABLE 1. Sociodemographic characteristics of heads of households[a]

Characteristic	Participating households	Nonparticipating households	p
Age (yr)	54 ± 14.93	55 ± 15.7	0.542[b]
Household size	5 ± 3.24	7 ± 3.34	0.000[b]
Sex			
Male	84 (54.9)	78 (48.8)	0.165[c]
Female	69 (45.1)	82 (51.3)	
Marital status			
Married	48 (31.6)	50 (31.4)	0.564[c]
Living together	37 (24.3)	29 (18.2)	
Lost spouse	27 (17.8)	31 (19.5)	
Never married	40 (26.3)	49 (30.8)	
Education			
None	95 (62.5)	84 (53.8)	0.156[c]
Some primary	37 (24.3)	44 (28.2)	
Completed primary	16 (10.5)	16 (10.3)	
Junior secondary	4 (2.6)	12 (7.7)	

a. Plus-minus values are means ± SD. Other values are numbers of individuals followed by percentages in parentheses.
b. Student's *t*-test.
c. Pearson chi-squared test.

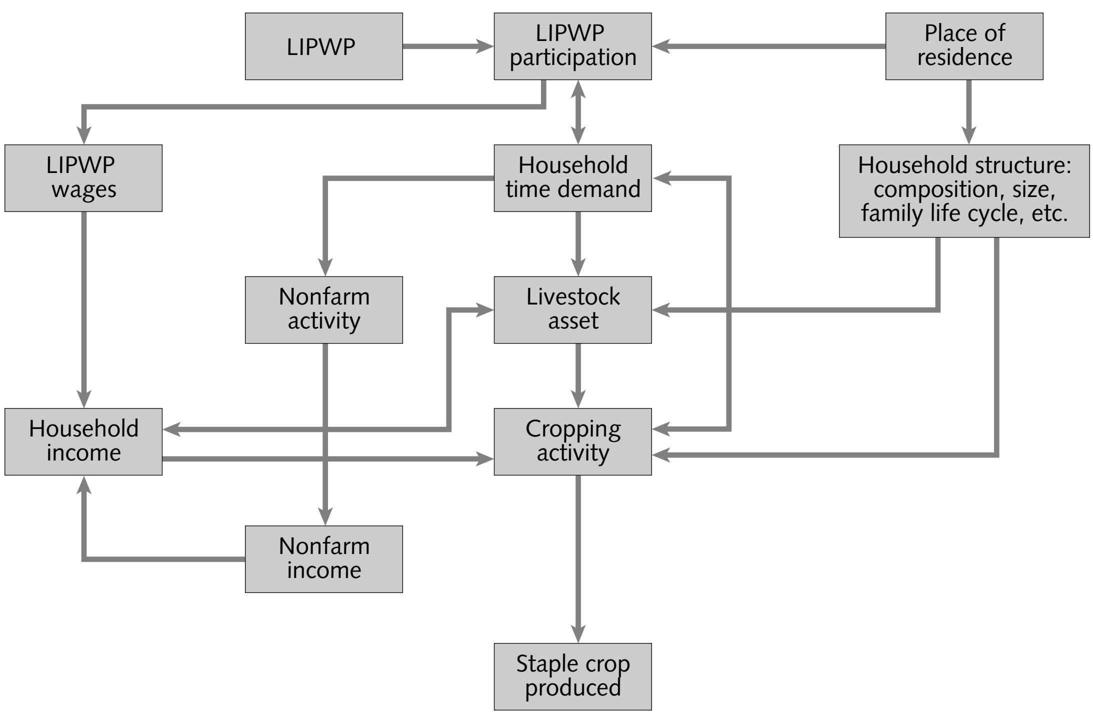

FIG. 1. Conceptual framework for analyzing the effect of LIPWP on staple crop production

There were 332 persons covered in this study, of whom 167 were participants and 163 were nonparticipants, suggesting that there were some households that had more than one participant or nonparticipant (table 2). The mean age of the participants was 45 years, ranging from 21 to 88 years, as compared with 38 years, ranging from 17 to 80 years, for the control group; 75% of the participants and 93.3% of the nonparticipants were women. The age difference between individual participants and controls is related to their main place of residence. In Botswana younger people have a tendency to reside in villages and towns, whereas older people live outside villages in cattle and land areas. Most of the LIPWP project sites are outside villages and tend to attract households from land and cattle post areas. Two persons were excluded from the analysis because their ages were unknown.

More participants than nonparticipants were married (26% vs. 20.2%). The difference is associated with the age distribution of the two study groups, as nonparticipants were younger.

TABLE 2. Sociodemographic characteristics of individual participants and nonparticipants[a]

Characteristic	Participants	Nonparticipants	p
Age (yr)	45 ±14.19	38 ± 14.43	0.000[b]
Sex			
Male	42 (24.9)	11 (6.7)	0.000[c]
Female	127 (75.1)	152 (93.3)	
Marital status			
Married	44 (26.0)	33 (20.2)	0.001[c]
Living together	47 (27.8)	27 (16.6)	
Lost spouse	19 (11.2)	11 (6.7)	
Never married	59 (34.9)	92 (56.4)	

a. Plus-minus values are means ± SD. Other values are numbers of individuals followed by percentages in parentheses.
b. Student's *t*-test.
c. Pearson chi-squared test.

TABLE 3. Household livestock assets[a]

Asset	Participating households	Nonparticipating households	p^b
No. of cattle			
0	69 (45.1)	98 (61.3)	0.013
1–6	22 (14.4)	24 (15.0)	
7–14	30 (19.6)	19 (11.9)	
≥15	32 (20.9)	19 (11.9)	
No. of LSEUs[c]			
≤10	94 (61.8)	125 (78.1)	0.001
>10	58 (38.2)	35 (21.9)	

a. Numbers are followed by percentages in parentheses.
b. Pearson chi-squared test.
c. One livestock equivalent unit (LSEU) is equivalent to 1 cow, 3 donkeys, or 6 goats or sheep [13, 14].

Household assets

Livestock is an important asset in subsistence farming in Botswana, because it provides food and draft power for crop production. In this study, 45.1% of participant households and 61.3% of controls did not own cattle (table 3). In terms of livestock equivalent units (LSEUs), 61.8% of participant households and 78.1% of nonparticipant households had 10 or fewer LSEUs ($p = .001$).

Staple crop production

Of 261 households with access to land, 67.8% (177) reported that they plowed their land in the reference plowing season. Only 33.9% (60) of the 177 households obtained some harvest.

Participation in the LIPWP, livestock asset, and age of the head of the household appear to be associated with staple crop production. More participant than control households produced some staple crop ($p = .070$) (table 4). With respect to age, 51.6% of households whose head was less than 45 years old and 31.2% of households whose head was at least 45 years old reported having some staple crop harvest ($p = 0.027$). Further, 41.6% of households with more than 10 LSEUs produced some staple crop, as compared with 28.3% of

TABLE 4. Staple crop production according to household sociodemographic characteristic[a]

Characteristic	No production	Some production	p^b
Participating households	57 (60.6)	37 (39.4)	0.070
Nonparticipating households	60 (72.3)	23 (27.7)	
All households	117 (66.1)	60 (33.9)	
Household size			
1–3	33 (67.3)	16 (32.7)	0.498
4–6	37 (68.5)	17 (31.5)	
7–9	20 (55.6)	16 (44.4)	
≥10	27 (71.1)	11 (28.9)	
Age of household head (yr)			
<45	15 (48.4)	16 (51.6)	0.027
≥45	95 (68.8)	43 (31.2)	
Education of household head			
None	74 (69.2)	33 (30.8)	0.133
Some	40 (59.7)	27 (40.3)	
No. of LSEUs[c]			
≤10	71 (71.7)	28 (28.3)	0.046
>10	45 (58.4)	32 (41.6)	

a. Numbers are followed by percentages in parentheses.
b. Pearson chi-squared test.
c. One livestock equivalent unit (LSEU) is equivalent to 1 cow, 3 donkeys, or 6 goats or sheep [13, 14].

those with 10 or fewer LSEUs ($p = .046$). Educational status and household size were less important.

Effect of participation, age of the head of the household, and LSEU on crop production

This section presents statistical modeling results on the effect of participation in the LIPWP on staple crop production. In choosing a statistical analytical model, consideration was given to the type of outcome variable and assumptions about the distributions of the explanatory variables. Because the outcome variable was binary, a stepwise logistic regression modeling technique was performed to assess key explanatory variables while controlling for potential confounders [16].

All of the eight variables were sequentially included in the model. The results are presented in table 5. Contrary to our hypothesis, place of residence, household size, marital status, educational status, and sex of the head of the household were not important determinants of staple crop production in the study area. Step 6 was chosen as the appropriate model because it presented the best goodness of fit ($p = .030$). Nagelkerke R-Squared (R^2) was used to determine the amount of variability explained by the model.

Table 6 presents logistic regression modeling results for estimated adjusted effects of participation, LSEU, and age of the head of the household on staple crop production. The final model explains 8.6% of the variability. The odds of having no harvest was 1.8 times higher for controls than for participant households (95% CI, 0.98 to 3.54) after adjustment for the age of the head of the household and LSEUs. The odds of having no harvest were 2.5 times higher for a household whose head was between 45 and 64 years old than for a household whose head was less than 45 years old (95% CI, 1.06 to 5.96). Households whose head was at least 65 years old were 3.1 times more likely to have no harvest than those whose heads were under 45 (95% CI, 1.21 to 8.22), after adjustment for LSEU. Having livestock was found to be important in reducing the risk of having no harvest. Possessing more than 10 LSEUs reduced the likelihood of having no harvest by 40% (95% CI, 0.29 to 1.12).

Discussion

The general view that participation in the LIPWP promotes dependency, resulting in reduced staple production, is not supported by our results. The effect of participation in the LIPWP on staple crop production appears to be neutral. If anything, participation in the LIPWP may have a positive effect on staple crop production.

TABLE 6. Estimated adjusted effects (odds ratios and 95% confidence interval) of participation in LIPWP, age of head of the household, and LSEUs on crop production

Characteristic	OR	95% CI	*p*
Study group			
Participants[a]			
Nonparticipants	1.8	0.98–3.54	0.087
Age of household head (yr)			
<45[a]			
45–64	2.5	1.06–5.96	0.037
≥65	3.1	1.21–8.22	0.019
No. of LSEUs[b]			
≤10			
>10	0.6	0.29–1.12	0.103

Nagelkerke $R^2 = 0.086$
OR, odds ratio; CI, confidence interval.
a. Reference category.
b. One livestock equivalent unit (LSEU) is equivalent to 1 cow, 3 donkeys, or 6 goats or sheep [13, 14].

TABLE 5. Staple crop production model (dependent variable: staple crop produced per household during the 1998–99 cropping season)

Model					Step			
Step	$\chi 2$	DF[a]	Nagelkerke R^2	Significance	Variable deleted[b]	$\chi 2$	DF[a]	Significance
1	15.191	12	.121	.231				
2	15.098	11	.121	.178	RESIDENCE	.092	1	.761
3	14.306	9	.115	.112	HSIZEGRP	.793	2	.673
4	12.426	6	.100	.053	MARITGRP	1.879	3	.598
5	11.669	5	.094	.040	GROUPEDU	.757	1	.384
6	10.677	4	.086	.030	SEXHD	.992	1	.319
7	8.386	3	.068	.039	LSUGROUP	2.290	1	.130
8	3.820	1	.032	.051	HAGEGR	4.567	2	.102

a. Degrees of freedom.
b. List of variables: RESIDENCE, Dummy variable = 1, if village (else=2); HSIZEGRP, Household size group in adult equivalent persons; MARITGRP, Marital status of head of household category; GROUPEDU, Head of household formal schooling category; SEXHD, Sex of head of household; LSUGROUP, Number of livestock in livestock equivalent units category; HAGEGR, Age category of head of household at last birthday.

Because of a lack of literature on the effect of the LIPWP on staple crops, we draw a lot from the findings of studies on other rural development schemes, especially small-scale agricultural commercialization. Part of the reason is that the LIPWP and small-scale agricultural commercialization schemes share some common features. First, they aim to improve household rural income without affecting staple crop production. Critics of both programs argue that they cause a decline in staple crop production, which could affect food intake and nutritional status [8]. In Gambia, adoption of a new technology increased communal crop production (millet, sorghum, maize, and rice) [17], although there was an observed shift of control of crops from women to men. In another cross-sectional study carried out in Swaziland, household food availability depended on whether a commercial crop was food or nonfood [18]. The focus on food consumption presents comparison difficulties, since the source of food consumed could be from non-crop-farming activities.

In Nyanza, Kenya, the mean percentage of land under food crops was significantly smaller for commercial sugar farmers than for non-sugar farmers; the former produced more food crop for consumption than the latter group because of increased crop yield per hectare [19]. The study further found that farmers who had diversified their income source were better off in terms of food consumption and overall income. Others have also shown income diversification among farming households to be the key to improved livelihoods [20]. In Botswana the share of rural nonfarm income increased from 54% in 1976 to 77% in 1986 [5]. However, a cross-sectional study on tree cropping among smallholders in Sierra [21] found a significant reallocation of land and labor resources, resulting in declining food availability.

In most of these studies, landlessness and labor appear to be a problem. However, in Botswana, as in most other sub-Saharan African countries, land and rural labor are in abundance [22]. The results of our study show that productive resources and age of the head of the household appear to be important. Ownership of livestock is also an important factor in staple crop production, partly because livestock, especially cattle, are an essential source of draft power. Others have reported that 90% of households with no cattle fail to cultivate any land in Botswana [23]. Cattle ownership has also been associated with better nutritional status of children under five years old [24]. Surprisingly, age increased the risk of obtaining no staple crop harvest. Households headed by older persons were more likely to obtain no harvest than those headed by younger persons. The reason for this is unclear. Households with older heads were expected to own more livestock assets that they could use for crop production.

The suggestion that as wages increase, women participants in the LIPWP are replaced by men is not supported by our data. In India the share of women among employment guarantee scheme (EGS) participants declined as wages increased [9]. This was in part attributed to the adoption of a piece-rate wage system that discouraged women from fully participating. The LIPWP in Botswana uses the same system of operation. However, we observed a significant increase in the proportion of women participating in the LIPWP from 24% in 1986 [25] to 75% in 2000. This is consistent with the findings of the 1994–95 labor survey, which reported that 75.6% of those involved in the LIPWP were women [26]. The rise in women's participation coincided with a shift from road construction to maintenance.

Study limitations

The bags most commonly used by the farmers were the 70-kg bags. Because the type of bags used was not observed, it was possible that some households used different sizes of bags to put their harvest in. In similar situations, others have concluded that any biases in estimating actual measurements would be common to both groups [12]. In addition to measures of crop produced, the total hours worked per participant during the employment period and the distribution of these hours over the crop year would have strengthened our results. Because the survey was conducted during a drought year, some factors, such as household size and sex of the head of the household, that could have influenced the dependent variable might have been diminished.

The difficulty in nonexperimental studies is that causality is difficult to establish, because the subjects are not randomly allocated to the groups. In observing free-living populations, randomization is not always possible. Participants in LIPWPs and LBDRPs are active thinking persons, making choices, functioning on their own, acting, and doing things, as opposed to sample populations in a laboratory setting. Field validation was employed to ensure that the two study populations were as comparable as possible under such circumstances.

Summary and conclusions

There is a growing concern that participation in the LIPWP draws labor away from subsistence staple crop farming, resulting in a decline in staple crop production. Part of the concern arises from the fact that policy makers have a tendency to assume that farm households depend mainly on their own crops for food security [27]. However, our data indicate that despite the high risk posed by adverse weather conditions and poor soils, the majority of participants in the LIPWP continue to grow staple crops for domestic consumption. In semiarid, drought-prone countries like Botswana, subsistence crop production appears to be an undependable source of livelihood. In formulating programs for household food security and reduction of income poverty, policy makers need to take this into account. Since Botswana has a well-developed market, ensuring adequate distribution of food, households ought to be encouraged and supported to earn off-farm income to purchase food.

Self-screening appears to have succeeded in targeting women, since they constitute most of the people living below the poverty datum line. It is important to determine whether the findings can be repeated in a nondrought year. More research is needed on this subject to be definite about observed changes. Further, we need to examine whether the effect of participation in the LIPWP can be translated into measurable nutritional improvement and to understand the possible pathway.

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International Food Policy Research Institute (IFPRI) Research Report 118
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Seasonal undernutrition in rural Ethiopia: Magnitude, correlates, and functional significance

Anna Ferro-Luzzi, Saul S. Morris, Samson Taffesse, Tsegaye Demissie, and Maurizio D'Amato

Marked seasonal variability of both production and consumption is characteristic of virtually all farming systems in the developing world. Seasonal variations in food security are linked to many other structural and economic problems, including agricultural stagnation and poor markets and infrastructure. Such conditions prevail in Ethiopia, where the decline in cereal production since the 1960s, the dearth of rural infrastructure, and poorly functioning markets are major determinants of the country's notorious periodic famines. The widespread mortality and disease that accompany these famines are well documented, but less is known about the effects of seasonal energy stress in the "normal" years in between. It is therefore crucial to understand the effects of the seasonal energy stress that forms the background against which the more devastating effects of large-scale famine are drawn.

Understanding seasonal energy stress

Seasonal energy stress arises when dwindling household food stocks and purchasing power result in reduced energy intake, even as energy needs to produce the next season's food supply increase. More fortunate rural households find ways to avoid or resist seasonal energy stress, but many experience significant loss of body weight. Seasonal loss of body weight in adults and impaired growth in children have significant human costs. In populations that lack large body fat stores, much body weight loss consists of loss of lean tissues, such as muscle and internal organs. Adults with very low body weight are more prone to illness, which can decrease income-generating capacity and cast the entire household into a downward spiral of impoverishment, debilitation, and undernutrition. Stunting in childhood is also associated with irreparable damage to cognitive function and increased susceptibility to disease.

This study examines the magnitude and significance of seasonal undernutrition in south-central Ethiopia in southern Shewa and Zigwa Boto, a peasant association in the Gurage Zone. These settings are vulnerable to even small stresses because of their extreme poverty and isolation. The study seeks to answer five questions:

- Does seasonal energy stress affect individuals of various age groups and sexes differently?
- Do members of the same household show divergent responses to seasonal energy stress?
- What are the functional consequences of different levels of adult undernutrition?
- Are the current anthropometric cutoff points for adults appropriate for rural Ethiopia?
- What household characteristics are associated with vulnerability to seasonal undernutrition?

How policy can help reduce seasonal undernutrition

A number of important findings emerge from this research, even though the case study approach may make it difficult to generalize these to other areas of Ethiopia.

First, the problems of seasonal weight loss and chronic undernutrition are intimately linked. Among adults of both sexes in southern Shewa, chronic undernutrition is more common than weight loss at virtually all ages. The research suggests that Ethiopian parents may be "protecting" the nutritional status of their school-age children, who show almost no impact of seasonality. Adolescents are much less affected than adults. Government investments in education and training could reinforce this behavior.

Second, seasonal undernutrition is highly unpredictable; the impact of seasonal stress varies considerably within localities and within households. As a result, central authorities may find it difficult to target seasonal safety-net interventions appropriately. A large number of self-targeting public works programs have been implemented in Ethiopia, and these appear to have been reasonably successful in reaching more vulnerable segments of the population. In addition, community-based organizations have far better local information than central authorities and therefore may be better equipped to implement small-scale insurance and relief programs.

Education, livestock holdings, and health are potentially important areas for intervention. Education of the household head strongly protects against seasonal undernutrition in adults but not against chronic undernutrition. This finding supports investment in education as a long-term solution to seasonal undernutrition.

Households with more livestock are also less prone to seasonal undernutrition in adults and to seasonal wasting in children. In the highlands of Ethiopia, the labor-saving benefits of oxen may reduce the energy stress on adult men. Livestock also offer a form of savings that can be liquidated in times of hardship. Improving the livestock asset base of households at risk might therefore be a promising approach to protecting vulnerable households.

Finally, at least for young children, seasonal weight loss appears to be much more strongly associated with seasonal patterns of diarrheal disease than with seasonal changes in food availability in the household. Initiatives that reduce diarrheal disease are an integral component of rural development in areas with marked seasonality. The impact of seasonal energy stress on the incidence of low birthweight is also important. Supplementary feeding of pregnant women in the hungry season has been shown to be an effective intervention.

The study clarifies some points of contention in the field of adult undernutrition. First, this analysis strongly suggests that proposed cutoffs for body mass index (BMI) provide meaningful classifications of undernutrition, at least for men. Second, the data from Zigwa Boto show that adults are unable to "adjust" to undernutrition, either metabolically or mechanically. Third, seasonal undernutrition is more common among men than among women, and men's functional capacity appears to be much more sensitive to weight loss than women's. Because men do the bulk of agricultural work in the area studied, improving their nutritional status is imperative.

Finally, seasonal undernutrition is merely one symptom of numerous problems in rural Ethiopia that include poorly developed labor markets, lack of financial resources, inadequate investment in human capital, and environmental degradation. This study shows how seasonal undernutrition operates as an intermittent warning signal, reminding us not to miss opportunities to promote good nutrition throughout the life cycle.

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The Egyptian food subsidy system: Structure, performance, and options for reform

Akhter U. Ahmed, Howarth E. Bouis, Tamar Gutner, and Hans Löfgren

Egypt's food subsidy system has been a mainstay of the government's long-term policy of promoting social equity and political stability. It has also been a major component of the social safety net for the poor, guaranteeing the availability of affordable staples, helping to reduce infant mortality and malnutrition, and mitigating the adverse effects of recent economic reform and structural adjustment. The cost of the system has declined considerably from 14% of government expenditures in 1980–81 to 5.6% in 1996–97. The absolute cost, however, remains high: in 1996–97, the total cost was 3.74 billion Egyptian pounds (LE) or about US$1.1 billion. The government and various stakeholders agree that the system's costs can be further reduced and its efficiency improved with better targeting to the needy.

This report evaluates the economic, political, and technical feasibility of reducing costs while improving or maintaining the welfare of the poor. The report addresses five questions: How well does the present system target the poor? How much leakage—the pilferage of subsidized foods in the distribution channel—occurs? At what cost does the government transfer income to the needy? How can subsidies be better targeted to the needy? What are politically feasible options for reform?

The subsidy system includes four foods: *baladi* bread, wheat flour, sugar, and cooking oil. Baladi bread and wheat flour are available to consumers of all income levels without restrictions. Sugar and cooking oil are targeted, being available only to those with ration cards. In principle, higher-income households should get low-subsidy red ration cards and lower-income households should get high-subsidy green cards.

Targeting the needy

The present system does not target the poor as well as it should. Subsidy benefits are about equally distributed across income groups: 1% of the population receives more or less 1% of the benefits. This distribution pattern is quite similar to that in the early 1980s and reveals that the majority of benefits accrue to the non-needy. Poor targeting combined with system leakage led to only about one-third of the subsidy going to the needy. Baladi bread accounted for 65% of this, wheat flour for 13%, sugar for 12%, and cooking oil for 10%.

Baladi bread and wheat flour accounted for about 77% of the subsidy in 1997. The untargeted system for these goods allows all consumers to benefit, but it is an expensive way to improve the food security and nutrition of the poor.

Sugar and cooking oil subsidies are not well targeted. A majority of the wealthy households (about 71% of households in the top three quintiles) carry the high-subsidy green ration cards. These households receive about 62% of the rationed subsidy benefits. On the other hand, about 10% of needy households hold the low-subsidy red cards, and about 14% of poor households have no card of any kind.

Food subsidies can be better targeted to the poor. For this to occur, the following measures are needed:

- Baladi bread distribution outlets should be concentrated in poor neighborhoods. Currently in urban areas, the per capita number of baladi bread outlets in wealthy neighborhoods is greater than in poor ones.
- Rural areas and other areas where poverty is concentrated should receive higher shares of total food subsidies. A strong urban bias exists in the allocation of subsidies across Egypt. According to the 1996 census, 57% of the population lived in rural areas, but only 30% of food subsidies were allocated to these areas in 1996–97. Moreover, governorate-level allocations do not consider the geographic distribution of poverty.
- The ration card system for sugar and oil should provide high-subsidy green cards only to low-income households, and should convert the green cards of non-needy families to low-subsidy red cards.

- The government should mix maize flour with baladi wheat flour at flour mills. Intermediaries would not then be able to sift the mixed flour to separate the higher-quality wheat flour to sell at market prices.
- A proxy means test, which relies on indicators highly correlated with household income, should be applied to distinguish poor from nonpoor households.

Leakage and cost-effectiveness

Considerable leakage occurs, because the subsidies create a strong incentive for intermediaries to sell subsidized foods illegally at market prices. Twenty-eight percent of subsidized wheat flour leaked in this way, 20% of sugar, 15% of cooking oil, and 12% of baladi bread.

Overall, the government spends LE3.06 to transfer LE1.00 of income to a needy household through the food-subsidy system. The cost of transferring LE1.00 to general consumers of baladi bread is LE1.16. But because 61% of the benefit from the baladi bread subsidy goes to the non-needy, the cost of reaching a needy household increases to LE2.98. At LE4.64, the cooking oil subsidy is the least cost-effective in directing LE1.00 of income to the needy. The costs of transferring LE1.00 of benefits to needy consumers through the sugar and wheat flour subsidy system are LE3.34 and LE3.71, respectively.

The current baladi bread subsidy provides a relatively effective means of transferring benefits to the poor, particularly the urban poor, helping to protect them against shocks that may arise from the ongoing economic reform process in Egypt.

Practical reforms

A number of reforms are administratively and politically feasible. Because there is no pressing need for far-reaching change, government officials and various stakeholders believe that extreme measures, such as increasing the baladi bread price to eliminate the subsidy or targeting bread subsidies by using food stamps or coupons, are unrealistic. The feasible reforms can be divided into two groups, based on the degree of political opposition they would probably encounter. Policies that would probably meet little opposition include revamping the ration card system by decreasing rationed food subsidies for the non-needy, and mixing maize flour with baladi wheat flour at the milling site to reduce leakage.

Options that would engender greater opposition are eliminating the sugar and oil subsidies, targeting bread outlets to poor neighborhoods, and reallocating supplies to the governorates according to their poverty levels. The losses the non-needy would incur from these reforms do not appear to be large. Therefore, these options are feasible if the political will exists to implement them.

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In Memoriam

Beat Schürch, 1940–2002

Beat Schürch, died on September 6, 2002 in Lausanne, Switzerland of malignant melanoma. His contributions to human nutrition resource development and his support of good research in developing regions will live long after him. He was born in Thun Switzerland on September 24, 1940. After obtaining a B.Sc. from the University of Geneva, he received M.Sc. and M.D. degrees from the University of Bern. In 1975 he received a Ph.D. in Instructional Technology and Educational Psychology from Syracuse University in the United States. He married Vinita Kapila in 1976 and their son Alex is 18.

Before coming to the Nestlé Foundation, he was Associate Professor and Director of a M.Sc. Program in Biomedical Communications at the University of Texas School of Allied Health Sciences at Houston, Texas, USA. From 1967 to 1973, he was the designer and producer of 50 television programs for continuing medical education for "Medicovision" Roche, Basel and 12 films for continuing medical education for Documenta Geigy. He was a longtime member of the IUNS Committee on "Nutritional Terminology."

As Director of the Nestlé Foundation for the Study of Problems of Nutrition in the World in Lausanne, Switzerland since 1979, he initiated an international fellowship program in human nutrition to strengthen nutrition institutions in low-income countries, particularly in Africa, that was highly effective. His determined support of excellence in the research capacity of selected nutrition units reinforced the benefits of the fellowship program.

Some of the Foundation's most important contributions have been support of research on maternal nutrition during pregnancy and lactation with emphasis on the many questions relating to infant malnutrition and its effect on later child health, growth, and motor and mental development. Beat Schürch's early recognition of the significance of evidence for the fetal origins of adult disease reinforced these efforts.

He supported improvements in mass spectrometry that made feasible the doubly-labeled water method for the unobtrusive assessment of total energy expenditure in free-living individuals over a two- to three-week period. When the International Dietary Energy Consultative Group (IDECG) was formed in 1986 with Beat Schürch as Executive Secretary, he initiated another long series of valuable contributions. He first arranged for IDECG, in collaboration with the International Atomic Energy Agency (IAEA) in Vienna, to bring together the heads of all the laboratories using this method at that time to standardize the technique and discuss its potential and limitations. This resulted in a rapid expansion in the use of the method and the collection of a wealth of data on total energy expenditure of different population groups and put into doubt many earlier estimates of their habitual energy intakes.

IDECG began as an informal network of scientists and policymakers interested in human energy metabolism and requirements, sponsored by the United Nations University (UNU) and the International Union of Nutritional Sciences (IUNS), with the endorsement of the UN Sub-Committee on Nutrition (SCN). Under Beat's extraordinarily effective guidance and ability to marshal the needed financial support, IDECG convened a series of workshops on seminal issues related to protein and energy metabolism and requirements.

The first workshop in Guatemala in 1987 considered chronic energy deficiency and its consequences. It concluded that the lack of an operational definition of chronic energy deficiency was a main obstacle to further progress. Low body mass index (BMI) was recommended as an indicator, and cut-off points for various degrees of chronic energy deficiency were defined. This led many scientists to collect more information on low BMIs and related conditions that allowed IDECG and

FAO to hold a follow-up meeting in Rome in 1992 at which the high prevalence and functional consequences of low BMI were dramatically highlighted.

In the meantime an IDECG working group met in 1989, in Cambridge, Massachusetts, USA, to review critically the existing data on activity, energy expenditures, and energy requirements of infants and children and provided new insights and recommendations. An IDECG meeting in Bellagio, Italy in 1990 analyzed and discussed the findings of a long-term follow-up of a longitudinal food supplementation trial in Guatemala. Energy and protein supplementation was shown to enhance human capital formation in adolescence and early adulthood as assessed by a wide range of variables.

An IDECG working group met in 1991, in Waterville Valley, New Hampshire, USA, to review and interpret current knowledge of the interactions between protein and energy requirements in health and disease. It confirmed the importance of this neglected issue for all estimates of protein requirements and provided guidelines for quantitative estimates.

In 1993 IDECG brought together in London, scientists who had made observations on causes, correlates, and patterns of linear growth retardation (stunting), with experts on the cellular biology and hormonal regulation of bone growth who could speculate on the mechanisms involved. It marshaled the evidence that children growing up in an unfavorable environment show delays in growth and behavioral development very early in life and suggested reasons and corrective actions. Its published conclusions have influenced social policy as well as research agendas.

For the next six years Beat devoted a considerable long-term effort to gathering, analyzing, and summarizing the two principal components of energy expenditure: basal metabolic rate and the energy cost of physical activity. A meeting in 1997 in Rome drew upon this information and established the lower and upper limits of adaptation to energy intake and its principal substrates, protein, carbohydrates, and lipids. The last in the series of IDECG workshops met in Boston in 1999 to discuss the impact of human aging on energy and protein metabolism and requirements. It provided new and valuable insights.

It is to Beat's credit that all of these meetings resulted in substantive publications, in later years as supplements to the European Journal of Clinical Nutrition. His concise annual presentations of the work of IDECG to the UN Subcommittee on Nutrition (SCN) were always appreciated. IDECG was able to play a valuable role in providing overviews of current knowledge, formulating research needs and priorities, and making conceptual advances in certain areas. As its Executive Secretary Beat Schürch deserves much of the credit for these achievements including the selection of topics, organizing the meetings themselves, and great skill in editing the workshop proceedings. He had an uncanny ability to identify issues to which IDECG could make important contributions.

Much of the above is taken from his own writing and interviews in which, with characteristic modesty, he did not present them as his own achievements although it was recognized that they were. One of his concerns was always to invite scientists from as many parts of the world as possible and to collaborate with other international organizations, particularly those of the UN system. No individual could have been more generous in accepting responsibility nor more conscientious in its discharge. He was also very knowledgeable in modern art, collected it, and was acquainted personally with many renowned artists.

Although he knew the prognosis of his disease many months in advance, he tried to spare his friends and colleagues this knowledge and the anguish of its inexorable progress. It is hard to accept the loss of someone so generous, committed, altruistic, and quietly effective who became a much-admired friend of nutritionists around the world. He was one of the nicest persons we have known. African nutritionists will particularly remember his commitment to their support. His contributions to the advance of nutritional science and nutrition scientists will have lasting influence as will his exemplification of dedicated and unselfish service.

Nevin S. Scrimshaw, Ed.

Books received

Consecuencias de la desnutrición en el escolar peruano. Ernesto Pollitt. Pontificia Universidad Catolica del Peru, Lima, Peru, 2001. (ISBN 9972-42-452-9) 417 pages, paperback.

The author of this book, Ernesto Pollitt, has contributed more than any single person to our understanding of the relations among nutrition, cognition, and school performance. The book is comprehensive, authoritative, clearly written, well illustrated, and carefully documented. It reviews the factors that determine the effectiveness of the educational system of a country and the evidence for the critical importance of good nutrition during pregnancy, preschool years, and school years. Peru is the example, but the implications and applications are universal.

Its key chapter on the effect of nutrient deficiencies on intellectual function and development reflects the author's research experience, objectivity, and critical judgment. The confounding effects of social status and poverty are well covered. Other chapters deal specifically with the factors responsible for protein–calorie malnutrition and its effects on intellectual development and educational achievement, poverty as a moderating factor on intellectual function, and the long-term consequences of retarded intrauterine growth.

Spanish-speaking readers are fortunate to have available this unique and outstanding treatise on the relations among nutrition, cognition, and education.

Homestead food production—A strategy to combat malnutrition and poverty. Edited by Martin W. Bloem, Saskia de Pee, Federico Graciana, Lynnda Kiess, Regina Moench Pfanner, and Aminuzzaman Talukder. Helen Keller International Asian Pacific, Jakarta, Indonesia, 2001. 129 pages, paperback.

This is a useful compilation in one volume of relevant articles published in a variety of journals, including four from the *Bulletin*. Its purpose is to make available the most recent experience with household and community gardens. Many of the papers are based specifically on experiences with the Helen Keller International-supported Homestead Food Production project. For those concerned with this important approach to food security and improved nutrition, this is a very convenient and readily available volume.

Iron deficiency and malaria as determinants of anemia in African children. Hans Verhoef. Universal Press, Veenendaal, Netherlands, 2001. (ISBN 90-5908-471-x) 191 pages, paperback.

Approximately three-quarters of East African preschool children suffer from anemia. Although most of it is due to iron deficiency, in regions with malaria it is an independent cause of anemia. Unfortunately, in most malarious areas iron deficiency is also a serious problem.

Where hookworm, malaria, and other conditions causing anemia are known to be important public health problems, the prevalence of iron deficiency can be assumed, and interventions to control these diseases must be integrated with those to address iron deficiency [1]. Iron deficiency does not protect from malaria. Where malaria and iron deficiency coexist [2], the 0% to 10% increased risk of malaria morbidity with iron supplementation, depending on the study, is far outweighed by the highly significant improvement in hemoglobin levels. Administering sulfadoxine pyrimethamine in addition to reduce infection gave no hemoglobin response.

This small paperback reports a randomized, controlled trial in anemic, asymptomatic children aged 2 to 36 months. It demonstrates that malaria-induced hemolysis is accompanied by an increased erythropoiesis that is sufficient to explain the degree of anemia. For those concerned with the role of malaria in anemia, this doctorate thesis report will be of interest.

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technical consensus on key issues. Boston, Mass, USA: International Nutrition Foundation, 1999.
2. Gillespie S. Major issues in the control of iron deficiency. Ottawa, Canada: Micronutrient Initiative, 1998.

Principles and methods for the assessment of risk from essential trace elements. Environmental health criteria 228. World Health Organization, Geneva, 2002. (ISBN 92-4-157228-0) 65 pages, paperback. Sw Fr. 26.00/US$23.40; in developing countries Sw. Fr. 18.20.

Nutrition workers must be aware of the effects of nutrient excesses as well as deficiencies. This is particularly true of the trace minerals. This slender paperback summarizes a great deal of useful information on the upper limits of safety for trace mineral ingestion. It emphasizes the extent to which the upper and lower limits differ markedly among elements. Iron, zinc, copper, and selenium are all examples of essential nutrients for which the scale of differences between deficiency and toxicity varies. Nutrition workers should have this convenient and up-to-date summary readily available.

The war within us: Everyman's guide to infection and immunity. Cedric Mims. Academic Press, San Diego, Calif., USA, 2000 (ISBN 0-12-498251-4). 278 pages, hardcover. US$39.95.

Understanding modern knowledge of the immune system is essential for any nutrition scientist, because its interactions with nutrition are major determinants of health. The December 2001 issue of the *Bulletin* favorably reviewed the book *Nutrition and Immunology: Principles and Practices*, and it remains the best source for those requiring detailed and documented information on this subject. However, students and professionals without the need for the original references and a more exhaustive treatment will find this volume useful and helpful. It is clearly written and well illustrated and has an adequate index, but its section on nutrition and immunity is brief. For persons specifically interested in the impact of nutrition on immunity, it would need to be supplemented from other sources, such as the one previously reviewed.

News and notes

LATINUT: A new forum on nutrition for Latin America

LATINUT resulted from an initiative of young researchers from different Latin American countries who participated in the first leadership workshop organized under a joint UNU/IUNS (United Nations University/International Union of Nutritional Sciences) initiative in Antigua, Guatemala, in September 1997 in conjunction with the SLAN (Latin American Society of Nutrition) meeting. The main objective of this forum is to utilize the growing capacity of the Internet to develop a network that can serve to enhance communication in the Spanish language between members and to discuss the science base and actions required to decrease malnutrition in the region. This idea was supported initially by the Institute of Nutrition and Food Technology (INTA), which provided the infrastructure and resources required to implement LATINUT as an independent website.

The forum has grown in the number of participants as well as in the variety of nutritional issues discussed by the membership. LATINUT has become an important place for approximately 200 professionals from the Latin American region to interact and discuss scientific literature, hot topics in nutrition, and issues related to clinical nutrition, as well as nutritional problems of public health concern. More recently, the Latin American UNU/IUNS program chose LATINUT to advance a regional network to develop and strengthen existing capacity for applied research and training required to enhance nutrition action in the region.

Currently the Institute of Nutrition and Food Technology (INTA) in Chile, the National Institute of Public Health (INSP) in Mexico, and a consortium of the Federal University of Pelotas (UFP) and the Public Health Department of the University of São Paulo in Brazil are part of this collaborative effort; other well-recognized institutions will surely join in the future. A recently funded project, "The Burden of Childhood Disease in Latin America: A Challenge for Health and Nutrition Research," supported by the WHO Global Forum for Health Research, serves as an initial base for this effort. The main objective of this specific project is the definition of a regional agenda for applied research in health and nutrition, based on the present and projected burden of disease and the existing capacity to conduct applied research. The process will culminate early next year with a regional meeting to analyze and approve an agenda for nutrition action in Latin America.

The *Bulletin* readership is invited to visit and participate in LATINUT (*http://latinut.net*) to obtain updated information on the different activities that are in progress. Priorities for action are being established for applied research in infant and child nutrition based not only on the main causes of death but on the concept of burden of disease (low birthweight, stunting, severe protein–energy malnutrition, micronutrient deficiencies, and the emerging epidemic of childhood obesity). It is also assisting regional and national centers in the establishment of applied research and training networks to address pressing nutritional problems such as micronutrient deficiencies (iron, zinc, copper, vitamin A, and iodine) and to collaborate in the development and strengthening of capacity aimed at the prevention of diet-related chronic disease.

Visiting LATINUT and interacting with other scientists and professionals related to nutrition provides an opportunity to obtain timely updates on different ongoing activities as well as to contribute to their progress. In addition, LATINUT will provide scientific information and discussion groups on protein–energy malnutrition and neonatal nutrition with updated articles and selected links directed mainly to the Spanish-speaking audience. We are planning to add sections on micronutrients, human lactation, social anthropology, and nutrition. We welcome you to participate in LATINUT and to increase regional interactions.

Gerardo Weisstaub, M.D., M.Sc., and Adolfo Llanos, M.D., M.P.H., for LATINUT

Iron Deficiency Program Advisory Service (IDPAS)

In 1997 the International Nutrition Foundation (INF) initiated the Iron Deficiency Program Advisory Service (IDPAS). IDPAS grew out of the experience of the INF and UNICEF over seven years of technical assistance on nutrition policy development, micronutrient interventions, breastfeeding promotion, and capacity building for nutrition research and program implementation in the four Central Asian republics and Kazakhstan. Focusing on the improvement of iron nutrition and anemia control in developing countries, IDPAS gathers and provides technical information, organizes working groups to clarify intervention strategies, and actively promotes exchange of information and experience among project-level specialists.

IDPAS promotes the major interventions of food fortification, oral supplementation, education for dietary change, infection control, related public health interventions, monitoring and evaluation, and program communication. In 1998 IDPAS organized an international working group meeting to clarify common technical issues that constrain the implementation of programs and projects for improving iron nutrition. The report and recommendations were supported by the Micronutrient Initiative, UNICEF, the World Bank, the United Nations University, and the World Health Organization.

In 2001 IDPAS developed protocols and provided technical assistance for a case study of cereal fortification in Venezuela and reviews of the anemia prevention and control programs in Kazakhstan, the Kyrgyz Republic, Tajikistan, Uzbekistan, and Turkmenistan. Since 2000, IDPAS has served as the secretariat for the iron activities of the Working Group on Micronutrients of the United Nations Standing Committee on Nutrition (SCN. In this capacity, IDPAS prepares a summary report by surveying partners around the world and compiling information on issues related to iron, folate, and zinc. The 2002 report was based on over 70 responses from 45 countries around the world.

IDPAS, along with the Centers for Disease Control and Prevention and the Micronutrient Initiative (MI), organized an international Working Group on “The Prevention of Iron Deficiency in Children Less than Two Years of Age.” The report of its meeting in Ottawa in September 2002 will be available early in 2003 and will be reported to the SCN at the same time.

IDPAS receives major funding from the Micronutrient Initiative of Canada to develop and use multiple communication channels in support of experts and projects focusing on improving iron nutrition in developing countries. Communication channels developed to serve these activities include e-mail and the Internet (*www.micronutrients.org/idpas*), an extensive list of contacts, and, as necessary, country visits by IDPAS consultants. Target groups are mainly those supporting work at the implementation level. By exploiting modern communication technologies, in particular the Internet, and the now widespread accessibility of computers, IDPAS has made its reference archives available to registered users through web pages, e-mail, widely distributed CD-ROMs, fax, and postal services.

The IDPAS electronic document collection, identified as IDPAS Iron World, includes over 1,100 references, many accompanied by full-text articles, books, manuals, international guidelines, and graphic materials. These relate to a broad range of topics important to those working in the general area of improving micronutrient nutrition and, more specifically, iron deficiency and anemia.

IDPAS also provides information useful for advocacy activities aimed at new projects involving micronutrient interventions. IDPAS Iron World provides up-to-date information both on issues with broad consensus by scientists and policy makers and on controversial issues, such as dosage protocols for iron supplementation, including iron supplementation in areas with a high prevalence of malaria and HIV-AIDS. Although IDPAS has concentrated on iron and iron-deficiency anemia, it is now including information on folic acid, zinc, and multinutrient supplements.

IDPAS was instrumental in organizing international support for a new decade UN target for reduction of the prevalence of anemia that focuses on the life cycle and targets all vulnerable groups, including young children. The target for a reduction of anemia prevalence by 30% in each country by the year 2010 has now been accepted by the UN General Assembly. IDPAS is promoting alliances to meet this goal and is providing comprehensive technical information, and disseminating experiences with implementation.

The IDPAS user network, which had grown to more than 390 persons from over 60 countries by June 2002, is continually maintained and updated. This list is a unique resource for international and bilateral agencies as well as nongovernmental agencies involved in the prevention of micronutrient deficiencies.

IDPAS responds to queries from researchers and program implementers from developing countries to provide information on current research and technical issues associated with applied programs. IDPAS also continues to assemble and make available comprehensive, country-level information to allow users to identify key individuals in specific countries or regions who can advise and assist researchers and project staff and share lessons learned from implementation activities. IDPAS Iron World users can ask the service to put them in contact with international and national experts in the field or in the laboratory regarding questions or advice.

Although most users in industrialized countries have access to the Internet, electronic access is often limited for those in developing countries. Therefore, IDPAS periodically places the contents of the entire IDPAS Iron World website onto a CD-ROM that allows users to access and search an archive of over 8,000 pages for research documents, various presentations, advocacy materials, graphics and training materials, and numerous other documents related to iron. IDPAS Iron World CD-ROMs are distributed free of charge throughout the developing world by UNICEF, MI, and SCN and through the IDPAS user network and contacts' database.

IDPAS services attempt to avoid duplication or competition with other groups and technical resources and provide linkages to their websites. IDPAS continually informs other organizations of its database and activities. It routinely refers requests for assistance to groups that have more resources to respond.

Registered users can review IDPAS web pages on the Micronutrient Initiative website: *www.micronutrient.org/idpas*. IDPAS can be contacted by e-mail (IDPAS@inffoundation.org), telephone (1-617-627-2291), or post at IDPAS, 126 Curtis Street, Medford, MA 01255, USA. Questions or comments can also be directed to Dr. Gary Gleason, IDPAS Program Director (ggleason@inffoundation.org).

Errata

In the Supplement to the Food and Nutrition Bulletin, volume 23, number 3, September 2002, there were errors in the following:

In the article on page 124 "Dietary intake of essential and minor trace elements from Asian diets," one author's name was misspelled, M. S. Nguy should be M. S. Nguyen, and the affiliations of the authors should be as follows: G. V. Iyengar and Robert Parr are affiliated with the Nutritional and Health Related Environmental Studies Section, IAEA, Vienna, Austria. H. Kawamura is affiliated with the National Institute of Radiological Sciences (NIRS) in Chiba-shi, Japan. F. K. Miah is affiliated with the Bangladesh Atomic Energy Commission, Dhaka, Bangladesh. J. Wang is affiliated with the Chinese Academy of Sciences in Tianjin, China. H.S.Dang is affiliated with the Bhabha Atomic Research Centre in Mumbai, India. H. Djojosubroto is affiliated with the National Nuclear Energy Agency in Bandung, Indonesia. S. Y. Cho is affiliated with Yongsei University, Wonju-kun, Kangwon-Do, Korea. P. Akher is affiliated with the Pakistan Atomic Energy Commission, PINSTECH, in Islamabad, Pakistan. E. S. Natera is affiliated with the Philippine Nuclear Research Institute in Quezon City, Philippines. M. S. Nguyen is affiliated with the Nuclear Research Institute in Dalat, Vietnam.

In the article on page 174 "Application of stable isotopic techniques in the prevention of degenerative diseases like obesity and NIDDM in developing countries" one of the authors, Chittaranjan Yajnik, was omitted. The authors should be Prakash Shetty, Venkatesh Iyengar, Ana Sawaya, Erik Diaz, Guasheng M, Manuel Hernandez-Triana, Chittaranjan Yajnik, Terrence Forrester, Mauro Valencia, Elaine Rush, Adebowale Adeyemo, Farook Jahoor, and Susan Roberts.

The Bulletin regrets these errors and apologizes to the authors for any inconvenience to them.

Note for contributors to the *Food and Nutrition Bulletin*

The editors of the *Food and Nutrition Bulletin* welcome contributions of relevance to its concerns (see the statement of editorial policy on the inside of the front cover). Submission of an article does not guarantee publication—which depends on the judgement of the editors and reviewers as to its relevance and quality. All potentially acceptable manuscripts are peer-reviewed. Contributors should examine recent issues of the *Bulletin* for content and style.

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1. Alvarez MI, Mikasic D, Ottenberger A, Salazar ME. Caracteristicas de familias urbanas con lactante desnutrido: un análisis critico. Arch Lationoam Nutr 1979;29: 220–30.

—corporate author:

2. Committee on Enzymes of the Scandinavian Society for Clinical Chemistry and Clinical Physiology. Recommended method for the determination of gammaglutamyltransferase in blood. Scand J Clin Lab Invest 1976;36:119–25.

Book or other monograph reference

—personal author(s):

3. Brozek J. Malnutrition and human behavior: experimental, clinical and community studies. New York: Van Nostrand Reinhold, 1985.

—corporate author:

4. American Medical Association, Department of Drugs. AMA drug evaluations, 3rd ed. Littleton, Mass, USA: Publishing Sciences Group, 1977.

—editor, compiler, chairman as author:

5. Medioni J, Boesinger E, eds. Mécanismes éthologiques de l'évolution. Paris: Masson, 1977.

—chapter in book:

6. Barnett HG. Compatibility and compartmentalization in cultural change. In: Desai AR, ed. Essays on modernization of underdeveloped societies. Bombay: Thacker, 1971:20–35.

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