FOOD SECURITY AND FOOD SCIENCES

ADVANCES IN FOOD TECHNOLOGY AND NUTRITIONAL SCIENCES

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# Table of Contents

## Editorial

1. Food Security and Food Sciences  
   – Malik Altaf Hussain
   Se1-Se2

## Editorial

2. Food Security: A Long Term Issue  
   – William W. Riley
   Se3-Se4

## Mini Review

3. New Strategies for Tracing Foodstuffs: Biological Barcodes Utilising PCR-DGGE  
   – Aly Farag El Sheikh
   S1-S7

## Mini Review

4. Microbial Resources to Safeguard Future Food Security  
   – Marzieh Hosseini Nezhad, Jafar Shafiabadi and Malik Altaf Hussain
   S8-S13

## Research

5. Application of Ultra Superheated Steam Technology (USST) to Food Grain Preservation at Ambient Temperature for Extended Periods of Time  
   – Md. Latiful Ban, Hisaharu Ohki, Kunio Nagakura and Mitsuko Ukai
   S14-S21

## Commentary

   – Andrew Method and Theodore H. Tulchinsky
   S22-S28

## Research

7. Post-Harvest Issues: Rethinking Technology for Value-Addition in Food Security and Food Sovereignty in Zimbabwe  
   – Gladys Mandisvika, Innocent Chirisa and Elmond Bandauko
   S29-S37
Mini Review

8. Inadequacies in Good Manufacturing Practices and High Health Risks are Still Problems in Food Production in Public Preschools and Daycares in Rio Branco, Acre, Western Brazilian Amazonia
   – Marzieh Hosseini Nezhad*, Jafar Shafiabadi and Malik Altaf Hussain

Mini Review

   – Malik Altaf Hussain*, Mohamed Elkhishin and Yu Sheng

Mini Review

10. Conservation of Rice Genetic Resources for Food Security
    – Roel C. Rabara*, Marilyn C. Ferrer, Mark Ian C. Calayugan, Malvin D. Duldulao and Jennifer Jara-Rabara
Food Security and Food Sciences

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Food security features as one of the dynamic and complex challenge that the humanity ever faced in its history. Before talking about inter-relationship between food security and food sciences, it would be worthwhile to review the most accepted definitions of both terms.

According to the Food and Agriculture Organization (FAO): ‘Food Security’ exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life.

According to the Institute of Food Technologists (IFT): ‘Food Science’ is the discipline in which biology, physical sciences, and engineering are used to study the nature of foods, the causes of their deterioration, and the principles underlying food processing.

Analysis of the nature of global food security challenge reveals that it is associated with several other issues; increasing world population, changing diet patterns, falling water tables, growing number of hungry individuals, deteriorating agriculture soils, decreasing agriculture yields, climate change, and running short of time. Yes, we are just over seven billion now and will be nine billion by 2050 on the same size planet – the earth. In other words, the world population clock is ticking continuously and every second passed adding to our total number dwelling on the earth. Therefore, complexity of this challenge demands urgent measures rather to assume that the food crisis situation will develop after couple of decades in 2030 or 2050. A single event that may create large scale emergency such as poor harvest in a vast region, drought or famine would be enough to disrupt the world food supply, thus could force thousands of families to go hungry and end up with life threatening situation, i.e., severe malnutrition or even death.

A time when world is heading toward potential shortage of food for human consumption, the news about possibilities to increase productivity and yields is grim. Agricultural productivity is vulnerable and poor crop and livestock yields are predicted due to several factors - climate change is one of the major one. Many reports have pointed out that climate change will alter the stability of food supplies and create new food security challenges as the world seeks to feed nine billion people by 2050.

The solution of food security challenge requires world to ensure supply of sufficient, safe and nutritious food to everyone on our planet. This is not a simple task and multiple sectors – science and education, research and development, social, political and regulatory changes need to move forward in a systematic and synchronised manner. Food science as a discipline has a lot to offer by maintaining the stability of food supply. A better understanding of the nature of changes in food with climate change could inform us more appropriate processing technologies. Therefore, food science and allied disciplines have a role to play in food process innovation, food safety and quality improvement and an efficient supply chain development. This will ultimately contribute to the availability of more and safe foods for a longer time period.

One example how food science will be able to improve food security is removing the food allergens through food processing. This could put more food on table for people with
specific conditions such as lactose or gluten intolerant. Another example where food science seems a major contributor is reducing the food wastage through improvement in food safety and quality as well as improved utilization. According to the United Nations, approximately 1.3 billion tons of food (about a third of the world’s food supply) was wasted in 2013. A reduction in this wastage will help to decrease the number of hungry individuals - currently 1.2 billion people are facing hunger and extreme poverty.

This special edition of Advances in Food Technology and Nutritional Sciences – Open Journal on “Food Security and Food Sciences” aims to highlight the food security challenge from a different angle and look at the possible ways offered by food sciences to address the issues impacting it. I also plan to contribute an article on ‘Food Product Innovation and Safety: Vital Elements of the Global Food Security’. We know there are many approaches that are suggesting the remedies of the potential food crisis situations at the moment. These approaches include: addressing global warming, droughts and climate change; increasing food productions; reduction in the world population growth; modernizing governmental policies; managing the fluctuation in food markets; and so on. Food science is a key player in new developing approach, which emphasizes to improve food systems and utilization through food product innovation, better food supply chain, preservation and storage as well as effective food safety management. I am optimistic about opportunity this special edition brings to us for presenting our position in tackling this global issue as food science professionals.
Editorial

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Food Security: A Long Term Issue

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Food security …..the term is often used, and a number of definitions have been offered for it. The United Nation’s FAO Committee on World Food Security offers this: “All people at all times have both physical and economic access to the basic food they need”. “All people,” at present, means more than 7.3 billion inhabitants of this planet, with that number growing by the day. In fact, despite efforts to the contrary, the world population continues to expand at an alarming rate relative to humanity’s past. Although Homo sapiens has inhabited this planet for over 2.0 million years, it took until the early 19th Century before its numbers reached 1.0 billion, but not even a century for the population to approach 2.0 billion. That’s correct, the human population of this planet stood at 1.6 billion at the start of the 20th Century, yet now, 115 years later, we are rapidly approaching 7.5 billion people on the planet Earth.

Although the last 50 years have seen a decrease in the rate of population growth, due to increased use of contraception, later age of marriage, especially for women, and a voluntary reduction in the number of children reared in the more developed countries, the reality is that the overall world population continues to grow. In particular, the developing world, which is least able to meet the FAO’s definition of food security, continues to record high birth rates. In 2014, the top three countries in the world for birth rates (all in Africa), recorded >40 births per 1,000 population. In comparison, the country with the lowest recorded birth rate last year, Monaco, had 6.7 births per 1,000 population.

At the current rate of growth, the Earth’s population is expected to reach 10.0 billion soon after the year 2050. According to the World Bank and the United Nations, 1-2 billion people in the world remain malnourished due to insufficient food, low incomes, and inadequate food distribution. If this trend continues to 2050 and beyond, we can expect 1.3-2.7 billion people to be in a similar circumstance. But hopefully, much of the rhetoric we hear about “feeding a hungry planet” will prove true. Certainly, to listen to vested interests in the agriculture and food sectors, we have only to continue to adopt new technologies to reach these starving masses and to meet the needs of the still unborn 2.5+ billion future inhabitants of the planet. Perhaps they are right. We can only hope so. But it is a daunting challenge indeed, particularly when we consider all the “gauntlets” that have been thrown down. “Crop yields will continue to increase, the developing world is just starting to eat meat at levels rivalling the developed world, so poultry, pork and beef production can continue to expand. Dairy consumption by heretofore low level consumers (e.g., Asians) has great upward potential”.

This all sounds like very positive news for the world’s hungry and especially for the world’s providers of these commodities. But few people have projected much beyond 2050. Instead, we hear about an expanding market (the population and its demand for food), and when it comes to feeding that market, we only talk about growth, growth, and more growth. Every company is going to grow its market, grow its sales, grow its profits. Yet, when does this growth “hit the wall”? That is, when is the population so high, and the food production so great, that we simply cannot sustain growth any longer? Is it in 50 years, or 100 years, or 200 years? Because those times will come, and not that long from now. Actually, 500 years and 1,000 years from now will eventually arrive as well. What will the world population be then, and how will it be sustaining itself at that point? Will every farm and every food and food-related company STILL be in a “grow at all cost” mode of thinking?
As a brief, albeit simplistic example, the Chinese swine industry has grown tremendously in the last two decades. In 1975, annual pork consumption per person in China was <10 kg. Now, it is close to 40 kg per person per year, surpassing the US annual per capita rate of consumption. In 2014, ~700 million pigs were slaughtered in China, accounting for ~51% of all the pigs slaughtered in the world. The Chinese industry, although suffering a recent setback due to disease problems, looks to the future with nothing but optimism from a growth perspective, and with the population soon to reach 1.5 billion and per capita meat consumption continuing to increase, there is every reason to believe that growth in this sector will continue its upward trend.

It’s easy to predict what this growth will look like in 2050, because on average, the Chinese swine industry has been expanding by 3-4% per year. This, of course, catches the eyes of the major world grain and oilseed producers, who see the opportunities that this will provide to expand soybean, corn, sorghum and barley exports to China. As well, animal feed additive and animal health companies have flocked to China, seeing the opportunities this expanding market offers for their products. But has anyone projected as to what the Chinese or the world swine industry would actually look like and require for grains and other feedstuffs to feed its animals in 100 years or 500 Years with even minimal continuous annual expansion (e.g., 1%)? Likely not, since we tend to think in terms of our lifetime and our comfort, notwithstanding platitudes about “future generations”. 

If 2014 statistics are used, then 723 million pigs were slaughtered in China. That represented 51% of all pigs slaughtered in the world that year, or ~1.418 billion pigs. That’s a lot of pork. But remember, we are going to “feed the world” with our technology and that means putting more meat into more mouths, so we will use a conservative figure of 1% growth in swine production to account for greatly expanded world per capita meat consumption in the next 100 years, as well as continued population growth (we assume). Then the number of pigs that will be slaughtered in 2115 will be 3.835 billion. If the growth rate in the swine sector over that time period is actually 2%, then there will be 10.273 billion pigs to process. It may be a leap in reproductive faith to think that the human population will still be increasing in 500 years (if Homo sapiens still exists), but 1% continuous growth in the swine herd around the world for that length of time would mean that we would have 205.3 billion pigs to process in the year 2515.

Those numbers are a bit sobering, and we did not even mention comparable growth in the poultry, dairy, beef, lamb or aquaculture sectors (the poultry sector is likely to expand at an even greater rate due to its more efficient production and its overall better acceptance throughout the world). Setting aside the issues of manure disposal and greenhouse gas emissions that swine and other livestock sector growth will generate, we would also need to address the increased demand for feed ingredients. At present, the world produces ~2.7 billion tonnes of total grains, legumes and oilseeds, with much of that being used for human consumption (i.e., rice, corn, wheat, etc.). In 2014, ~996 million tonnes of grains, oilseeds, plant and animal by-products were used to make compound animal feeds, and an untold quantity more of those grains and oilseeds were mixed on-farm to feed animals. Just to feed 3.835 billion pigs, at an average feed conversion ratio of ~2.7 kg of feed per kg of pig would require ~1.06 billion tonnes of feedstuffs (assuming 100 kg animals). Yet, swine feed accounts for only 25% of total world animal feed consumption, so there would be a need for >4.0 billion tonnes of grains, oilseeds, etc., just for animal feeds, not to mention the rice, corn, wheat and other agricultural products that are used for direct human consumption. Indeed, our plant breeders had better provide some miraculous increases in yields, because there is precious little new arable land on the planet to access. Even with improvements in animal feeding efficiencies (better feed conversion), at some point, growth will need to cease. The planet will simply not bear either further increases in the animal population or the grains, legumes and oilseeds that are needed to feed them. If the population actually begins to decline at some point in the future, then the need for more food will also decrease. But are we to count on that happening, and if so, when will it occur?

What are some of the potential solutions should our population continue to expand? The developed world over eats. The underdeveloped world under eats. One can draw the appropriate conclusion from that fact. In the animal production industry, producers go to great lengths to feed their animals the minimum amount of nutrients at the least cost to achieve the best performance. Yet, a large part of the human population eats to great excess, often to the detriment of its health and its pocket book. Animals are fed to their “need,” while we eat to our “want”. Can the guilty portion of the population continue this interminably?

We also think nothing of wasting food. At least one-third of all the food produced in the world is wasted. So, for those of us who believe that: “We can feed the world by increasing food production,” if the issue of food waste is not addressed, we will be increasing production so that we can throw one-third of it away. That is a waste of one-third of our resources and one-third of our time. In the developing world, most of the waste occurs post-harvest, because the proper supply chain mechanisms are not in place to keep food intact and safe before it reaches the consumer. For the developed world, food is, for the most part, simply thrown away. Some of that is inevitable, but much of it is inexcusable. Food security is an issue that will not go away, and it will grow in scope and importance with every passing decade. Let’s think of our future generations now, and contribute solutions to the problems that they will inherit.
New Strategies for Tracing Foodstuffs: Biological Barcodes Utilising PCR-DGGE

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ABSTRACT

Traceability of foods is undertaken primarily at the administrative level, and the use of advanced analytical tools is rare. Nevertheless, the determination of geographical origin is a demand of the traceability system for the import and export of foodstuffs (UE regulation 178/2002). It is hypothesised that foodstuffs can be traced at source by analysing food sample microbial communities after they have been exported. For this purpose, rDNA profiles generated by PCR-DGGE may be used to detect variability in microbial community (bacteria, yeast, fungi) structures inherent to fish, fruits and grains. This is an emerging traceability tool that imprints food with a unique biological bar code and makes it possible to trace food to its original location. In addition, this analytical technique provides a means to monitor and fully understand the ecology of mycotoxin producing fungi.

KEYWORDS: Traceability; PCR-DGGE; Microbial communities; Foodstuffs; Food safety.

INTRODUCTION

Food traceability is a growing consumer concern worldwide. In view of the difficulties involved in installing documentary systems in developing countries and in following foodstuffs through the production process, one possible approach is to identify and validate molecular fingerprinting based on the food’s environment to assure traceability. Currently, there are no analytical methods available that permit the efficient determination of foodstuff origin or that allow them to be followed during international trade. In case of doubt or fraud, it is necessary to find a precise and fast analytical technique to assign geographical origin.¹

The most popular analytical methods used to ensure the determination of origin are bar codes and stable isotopes.² Stable isotopes are currently used for reference by the EU to determine origin of wine.³ It thus seems difficult to use fruit genomic markers to ensure the traceability of Shea tree fruits. However, the skin of fresh fruits is not sterile and can carry microorganisms or their fragments. The presence of various microorganisms depend on the external environment of the fruit (soil ecology, spoilage, insects, diseases), but microorganisms also result from human activity.⁴ The use of molecular biological methods in general or by PCR-DGGE in particular have been described.⁵ These tools may be used to deliver reliable results in an efficient and acceptable manner to determine the origin of food products.

WHY DOES THE NEED ARISE TO USE MOLECULAR TECHNIQUES TO TRACE FOODSTUFFS?

In past years, the development of biological identification technologies has contributed to the industry’s ability to support and validate traceability systems. In parallel, computer technology has provided the industry with many new and innovative tools with which to trace...
products. Biological, analytical and informatics tools have been synergistically proposed and utilised for traceability in the wine industry. Currently, there are no molecular biological techniques available to determine the geographical origin of food. The idea was to create a “biological barcode” based on the analysis of the DNA of microorganisms present on the products. This method is based on the assumption that the microbial communities found on foodstuffs are specific to a geographical area.

**LINKAGE BETWEEN TRACEABILITY AND FOOD SAFETY**

Recently, tracking and tracing systems have become the most important methods used to ensure food safety, whereas food safety is an intrinsic part of food quality. A reliable traceability system means that a tool can allow a food company to track and trace any foodstuff which does not meet consumer expectations or the applicable regulations in an importing country. The main objective of a traceability system is to tell a product’s story, i.e., identify a unique product batch and the raw materials used in its production and follow that batch through its production and distribution all the way to the retailer. Today, tracking and traceability software tools are of major interest to the retail business (as a business to business communication tool). Tracking and traceability systems can be incorporated into information systems where consumers can receive information on any product. Traceability systems enable efficient product recall and allow fewer products to be recalled. This can bring important cost savings, where the aim is to provide consumers with nutritious and healthy products which are produced in a cost-efficient way.

**WHY PCR-DGGE?**

The Polymerase Chain Reaction-Denaturing Gradient Gel Electrophoresis (PCR-DGGE) is a well-established molecular tool in environmental microbiology which allows for the study of complexity and behaviour of microbial ecology. The PCR-DGGE is capable of providing a fingerprint of the microbial community in a food sample after direct DNA extraction (Figure 1). Briefly, a food sample is subjected to DNA extraction.
tion, with the attainment of a mixture containing DNA from the microbial species that is present in the sample. Successively, the DNA mixture is used as a template for PCR amplifications of specific variable DNA regions of taxonomic interest by obtaining an amplified product that is a mixture of amplicons from the species present in the initial sample. All amplicons are of the same size but with different sequences, and can be thus separated by DGGE. The final result is a fingerprint that is specific to the analysed sample and contains a series of bands relative to the microbial species that is present. Identification of the species can be achieved by purifying and sequencing the bands in the DGGE profile. The most commonly employed target for PCR amplification prior to DGGE is the ribosomal DNA. This is because ribosomal DNA is considered the most conserved gene in all cells inclusive of variable regions. The technique is reliable, reproducible, rapid, inexpensive and capable of analysing a large number of samples in a single step. DGGE is applied to the study of microbial diversity and can be coupled with techniques of cloning and subsequent sequencing. The PCR-DGGE has the advantage that separation does not depend on the size of the fragment, but rather on the melting behaviour of the PCR product. DGGE is more discriminating than is Restriction Fragment Length Polymorphism (RFLP). In addition, the banding pattern obtained from the PCR products is indicative of different species, or species assemblages, and allows visualisation of the genetic diversity of microbial population indices to quantify biodiversity, and it has the potential to find new noncultural microorganisms. One of the characteristics of strong DGGE is the ability to identify community members by sequencing and by re-amplifying bands excised directly from gels or by hybridisation analysis with specific probes, which is not possible with RFLP. Despite these limitations, DGGE is strongly preferred and is considered one of the best techniques for monitoring the microbial community of foodstuffs in a comprehensive, rapid and reproducible manner.

APPLICATIONS OF PCR-DGGE TECHNIQUE IN THE TRACEABILITY OF FOODSTUFFS

For this purpose, molecular techniques employing 16S rDNA profiles generated by PCR-DGGE were used to detect the variation in microbial community (bacteria, yeast, fungi) structures of fish, fruits, salt, cheeses, grains, and organic and conventional foods. These studies demonstrated that microbial communities were specific for each location, allowing for the foodstuffs to be differentiated. Several microbial species were identified as potential biological markers, whose detection could be used to certify the origin as well as the mode of production of the foodstuff.

PCR-DGGE Technique in the Traceability of Fish

Analysis of bacterial communities in fish samples has often been investigated using culture dependent methods and culture-independent methods by Random Amplified Polymorphic DNA (RAPD). Aquatic microorganisms are known to be closely associated with the physiological status of fish. The water composition, temperature and weather conditions can influence the bacterial communities. The predominant microbial flora (i.e., bacteria, yeast) would permit the determination of the capture area, production process or hygienic conditions during post-harvest operations, yet there are very few published works that provide an analysis of the microbial communities in fish samples by PCR-DGGE and differentiate geographical location.

PCR-DGGE Technique in the Traceability of Fruits

Fruits are included in the priority list of many governments’ horticulture and fruit export plans. For economic reasons and for profitability, batches of fruits representing various species or various cultures could be mixed. It is thus very difficult to check their exact geographical origin. Traceability is only assured by rigorous labelling and administrative documentation without proper analytical control. In case of doubt or fraud, it is necessary to find a precise and rapid analytical technique to determine their geographical origin. The PCR-DGGE method of analysis is a unique way to generically identify all microbial flora (bacteria, yeast, moulds) present on fruit, in order to create the linkage of microbial communities to the geographical origin and avoid the individual analysis of each strain. The acquired band patterns for the microbial communities of different species of fruits and different harvesting locations were compared and analysed statistically to determine the fruit geographical origin.

Figure 2 shows the DGGE pattern of the DNA of yeast communities of Shea tree fruits from two different regions of Mali, while figure 3 illustrates the cluster analysis of the DGGE gel patterns, which explains that the DGGE pattern of the DNA of yeast communities of Shea tree fruits was strongly linked to the microbial environment of the fruit.

PCR-DGGE Technique in the Traceability of Grains

As an example, coffee could be attacked by pathogenic microorganisms (including mycotoxigenic fungi) which could have a serious impact on coffee quality. The presence of various microflora depends on the external environment of the coffee (soil ecology, spoilage, insects, diseases), but also on microbial communities brought about by human activity. Fungi are responsible for coffee diseases (mildew and black rot), mycotoxin production, or sensorial defects in coffee such as musty or earthy aromas. Knowledge of the structure and diversity of the fungal communities of coffee beans would lead to a better understanding of the emergence of defects in coffee in relation to the fungi present on coffee beans. PCR-DGGE has proven to be a rapid and effective method that can be used to describe fungal communities on coffee beans. This confirms the idea put forward by Laforge et al., who showed that PCR-DGGE was an effective and quick.
Figure 2: DGGE Profiles of 26S rDNA for yeast strains isolated from Shea tree fruits from two different regions of Mali: Ségué region (D1, D2: Daelan sites) and Sikasso region (N1, N2: Naféguésites). 46

Figure 3: Cluster analysis of 26S rDNA profiles for yeast strains isolated from Shea tree fruits from two different regions of Mali: Ségué region (D1, D2: Daelan sites) and Sikasso region (N1, N2: Naféguésites). 46
method to follow food product fungal communities. Nganou et al.37 used PCR-DGGE to permit the certification of coffee origin by using 28S rDNA fingerprinting of moulds.

CONCLUSIONS: CHALLENGES AND PROSPECTS

Universal scientific methods for the determination of geographical origin of a foodstuff do not, in fact, exist. There are only indirect methods available, which often must be coupled together to increase their accuracy. Methods which permit the analysis of the micro environment of food are very promising and must be better studied by research teams around the world.11

PCR-DGGE is strongly preferred and considered one of the best techniques for monitoring the microbial communities associated with food samples in a comprehensive, rapid and reproducible manner. Also, by PCR-DGGE, it is demonstrated that there is a link between the microbial populations and the geographical area of origin of the foodstuff. So, this method is proposed to be an analytical traceability tool for foodstuffs.9

The main problem will be the construction of the data banks that are necessary for the PCR-DGGE technique. Other techniques will be developed in the near future, taking into account, for example, the micro-constitution of food. One could consider the micro-components of lipids like to copherols, phospholipids, sterols or other molecules brought into the environment, like pesticides, traces of insects, heavy metals, radioactive isotopes, et al.11

REFERENCES


Microbial Resources to Safeguard Future Food Security

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ABSTRACT

For thousands of years, microorganisms have been used to process foods and to produce a variety of useful compounds, including organic acids and enzymes from fermented food products. Currently microorganisms have been employed to manufacture biotechnological products that range from alcohol and antibiotics to cellular proteins on an industrial scale. The ability of microorganisms to convert less useful substrates to value-added end-products is considered to be a novel approach to enhancing the quality and quantity of the food and the feed that we and animals eat, respectively. Exploitation of such microbial properties is an effective way to improve the nutritional quality of food as a hedge against food shortages and hunger, particularly in low income communities. This article discusses utilization of microbial resources (i.e. yeast and bacteria) to improve global food security.

INTRODUCTION

Food security is achieved when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (1996 World Food Summit, Rome).1 Social problems can escalate the food insecurity and malnutrition in developing countries. They may result in a portion of the population being without access to sufficient levels of high quality food, and in many instances, a high percentage of this population may become malnourished. Microorganisms represent a natural resource that is available to developing and developed countries alike, which may be exploited through the field of biotechnology to supplement the current supply of food and energy.2 Three key discoveries in the field of microbiology have advanced the application of microbial resources within the area of food science. Firstly, there has been the realization that microorganisms can be isolated and manipulated to produce desirable fermented food products. Currently microorganisms have been employed to manufacture biotechnological products that range from alcohol and antibiotics to cellular proteins on an industrial scale. The ability of microorganisms to convert less useful substrates to value-added end-products is considered to be a novel approach to enhancing the quality and quantity of the food and the feed that we and animals eat, respectively. Exploitation of such microbial properties is an effective way to improve the nutritional quality of food as a hedge against food shortages and hunger, particularly in low income communities. This article discusses utilization of microbial resources (i.e. yeast and bacteria) to improve global food security.
In this review, the prospects and the potential to apply microbial tools in food production systems with the intent to improve both the quantity and quality of the food supply are explored. This article will improve knowledge and understanding of the application of microorganisms and microbial resources to address the challenge of food security.4

FOOD SECURITY, NUTRITION AND MICROORGANISMS

Food security describes a situation in which people do not live in hunger or in fear of starvation. The stages of food insecurity range from food shortage situations to full-scale famine. Availability of food, access to food, and risks related to either availability or access are the essential determinants of food security.

The commonly used definition of food security comes from the Food and Agriculture Organization (FAO) and the United States Department of Agriculture (USDA, 2000) as: “Food security exists when all people, at all times, have access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life”.5 Adequacy of food availability means that the food supply should potentially cover overall nutritional needs in terms of providing energy and all essential nutrients. At the same time, it should be safe, free of toxic elements and contaminants, and be of good sensory quality.

Considering projected world population growth and the increase in world demand for food over the next two to three decades, increase in food production must be achieved using less labor, water, cultivated land and/or unconventional resources. Microbial resources are being used to make or modify food products to enhance properties such as taste, shelf life, texture and nutritional value.

Microorganisms have been used widely for hundreds of years to produce various types of foods that are both nutritious and spoilage resistant. They play an important role in the conversion of ingredients into food; for example in the preparation of bread, cheese, yoghurt, fermented fish, fermented meat and vegetable products. The value-added bio-products are increasingly produced in technologically advanced countries for use in food processing. Biotechnology in the food processing sector makes use of microorganisms for the preservation of food and the production of a range of value-added products such as enzymes, flavour compounds, vitamins, microbial cultures and food ingredients. The selection and manipulation of microorganisms can lead to the production of food products and ingredients with improved processing, quality, safety, consistency and yield. These attributes of microbial tools demonstrate that bio-processing could contribute to food security by providing food elements, including protein, and minimizing the wastage and loss within the food supply chain.

Novel foods produced through the use of microorganisms can be categorized into three groups: (1) genetically modified viable microorganisms; an example is genetically modified lactic acid bacteria used in fermented milk, (2) foods produced from, but not containing, genetically modified microorganisms; an example is extracellular products of genetically modified microorganisms, such as vitamins, organic acids, etc., (3) foods isolated from microorganisms; these include new products based on single-cell protein production such as the fungus Fusarium graminearum, and omega-3 fatty acids derived from algae, like Cryptophyceae colnii and Nitzschia alba.6

Microorganisms as an Alternative Source of Protein

The demand for human food and animal feed proteins from non-conventional sources has increased, particularly in developing countries. Microbial protein can be considered a source of additional proteins in the diet. In this application, microorganisms primarily act as production agents rather than as principal raw material. The protein content may have high biological value, especially when methionine supplementation is used.6

Microbial cells grow rapidly and accumulate a high amount of protein. This could be a stable source of protein, as the cultivation of microorganisms under controlled conditions yields high biomass, and the process is less dependent on variations in climate, weather and soil.7 Microbial proteins must be evaluated for nutritive value, safety, and economic considerations before mass production is undertaken. Although animal proteins are considered the best quality proteins, microbial protein, also known as single cell protein, is one of the important optional proteins because of its higher protein content and the very short growth cycle of microorganisms, thereby, leading to rapid biomass production.8 Moreover, microbes are able to grow on inexpensive nutrient sources (substrates) to produce nutritionally rich biomass (source of high quality protein).

Such production of Single Cell Protein (SCP) for use in human food and animal feed is vital and offers the possibility to overcome a protein shortage, thus enhancing future food security. It is important to note that the microbial protein can become a major component of human diet. There will be less protein available from plant sources due to shortage of crop production and an increase in the demand for protein in future. In other words, microbial protein is crucially required to meet global needs, in particular, in populous regions.

Candida utilis has been used industrially in the production of SCP for food, waste treatment and the production of chemicals that are used as flavor enhancers.9 Yeast (Saccharomyces cerevisiae) is the most promising source used to produce single cell protein with inexpensive raw materials. It is also easy to harvest due to the larger cell size and flocculation ability with lower amounts of nucleic acids compared to bacteria.10 The microbial protein has also been reported to contain a more favourable balance of the essential amino acids and a better biological score than soya protein.11
The idea that SCP could be used on a large scale in food diets for human consumption has been denied because of the fear that it may contain some toxic compounds. This is not supported by any objective reasoning, since lactic acid bacteria are being digested directly through fermentation and in dairy products. The purine nucleic acids are the only SCP component which may cause problems if fluid intake is low. However, with sufficient liquid intake, there is no ill effect. Bacterial SCP is not unique in this regard, as some other foods, like meat and eggs, are rich in purines.13

Bioconversion of Agro-Industrial Wastes by Microorganisms and their Application

Agricultural activities and the food industry generate considerable quantities of residual plant biomass, which is considered to be “waste”. This “waste” is rich in organic matter, and it therefore has considerable value if it can be reconstituted into new materials to manufacture value-added products. At present, biodegradation is the main research direction for food waste resource processing methods.24 Potentially these huge amounts of waste can be converted into various different products, including biofuels, chemicals, cheap energy sources for fermentation, improved animal feeds and human nutrients and food. Agricultural wastes are widely available, renewable and virtually free, hence they can be important resources. They can be used to enhance food security mainly through their use as bio-fertilizers and soil amendments, animal feed, and in energy production. Many of them can be directly added to the soil without any risk to the environment.24 Therefore they should be considered as a resource that can be utilized and not just discarded. Many researchers have determined the feasibility of using agro-industrial wastes for microbial production and evaluated protein quality of Single Cell Protein (SCP) biomass.12,16,17

A diverse spectrum of microorganisms for efficient cellulose hydrolysis, mainly fungi and bacteria, have been isolated and identified, and this list continues to grow rapidly, although only a few microorganisms have been studied extensively and employed widely in commercial applications.18 Candida utilis has been used industrially in waste treatments. Two-step dual fermentation can be carried out using C. utilis with organisms like Saccharomycopsis fibuliger, which produces amylases and can be used in starch wastes, and Trichoderma reesei, which has cellulase and can be used in waste treatment.19

Olayinka discussed how appropriate application of microbial symbiots of plants such as Arbuscular Mycorrhizal Fun-gi (AMF) could improve food security by increasing the overall yield of important staple crops, irrespective of the mechanism by which it occurs (e.g. improved phosphate acquisition, improved drought or disease resistance).19 “Food security crops” refer to crops that can feed a significantly large number of people and that their yields fluctuate little during periods of major climatic perturbation.19,20

Pineapple waste was also used as sole carbon source in different concentrations for the preparation of fermentation media on which two strains of yeasts, S. cerevisiae and Candida tropicalis were grown.21 An increased concentration of pineapple hydrolysate enhanced the biomass yield and the protein formation within yeast cells. This study presented SCP production using pineapple wastes as an inexpensive and readily available agro waste substrate material.

Sabiti briefly reviewed how agricultural wastes could be used to enhance food security and conserve the environment. Although it is recognized that the accumulation of waste has enormous ill effects on humans and the environment, such waste if properly managed could be considered a bio-resource for enhancing food security in small holder farming communities that could not afford the use of expensive inorganic fertilizers. Microbial processing is a way to follow this target.13

Bacha, et al. studied S. cerevisiae production from potato and carrot peels. They suggested that this organism could efficiently use waste, and the biomass produced could potentially be used as a protein source in various food formulations.12

Fermentation and Food Security

Fermentation is one of the oldest transformation and preservation techniques for food.22 This biological process allows not only the preservation of food but also improves its nutritional and organoleptic qualities. Fermentation technologies play an important role in ensuring the food security of millions of people around the world, particularly marginalized and vulnerable groups. This is achieved through improved food preservation, increasing the range of raw materials that can be used to produce edible food products and removing anti-nutritional factors to make food safe to eat.21 Caplice, et al. reviewed the role of bacteria in the preservation of foods by fermentation and outlined a brief description of some important fermented foods from various countries.24

The major roles of fermentation are (1) preservation of food through the formation of inhibitory metabolites such as organic acids, bacteriocins, etc.; (2) improving food safety through inhibition of pathogens or the removal of toxic compounds; (3) improving the nutritional value and organoleptic quality of the food.22

Fermentation is a slow decomposition process of the organic substances that are present, induced by microorganisms or enzymes. Using bacteria and yeast, this was originally used as a method of preservation, but the process has been developed and understood further since then.25 The methods are now more fully exploited to alter the texture and flavor of foods as well as to incorporate substances which are beneficial to the health of consumers.25 Currently, the term fermentation is used to describe a special class of food products that are characterized by various
types of carbohydrate that are metabolized in the presence of microorganisms, but seldom is a carbohydrate the only constituent acted upon. These processes not only give food a pleasant taste, texture and smell, but it causes changes that reduce the growth of unwanted food microbes which improve the food’s storage life, food safety and security. Nowadays, fermentation is used to make a wide range of foods and beverages. The process improves the nutritional value of foods using easily available seasonal raw materials and without the requirement for sophisticated processes and infrastructure facilities. Therefore, it can play an important role in preventing food shortages. Fermentation is a cheap and energy efficient means of preserving perishable raw materials and is accessible to even the most marginalized, landless, physically incapacitated rural, peri-urban and urban poor.26

An authoritative list of microorganisms used in food was established as a result of a joint project between the International Dairy Federation (IDF) and the European Food and Feed Cultures Association (EFFCA). This list was published in 2002 by Mogensen, et al. Table 1 shows some of the important microorganisms used in the production of fermented foods.27

Fermentation technologies can play an important role in ensuring food security. Many researchers have emphasized this fact in their case studies. Betsche, et al. described fermentation as a tool which could be applied to improve the nutritional value of African yam bean.28 Quave, et al. discussed fermented foods for food security and food sovereignty and the role of fermentation in the production of local foods for health as well as its connections to community vitality.29 Moreover, there are several examples of fermentation by-products that can be safely fed to animals and hence further strengthen the livestock system.28 Food security can be achieved through improved food preservation, and increasing the range of raw materials that can be used to produce fermented food products. This technology, therefore, can be one of the tools which are used to combat the problem of malnutrition in developing countries.

**SUMMARY**

The world is facing a food shortage that will intensify in the next several decades as the global population increases. In addition to the obvious effects and enormous impact on human health, food shortages may cause political instability and challenge global stability.

Food shortage in developing countries demands exploration of new, innovative and unconventional protein sources to fortify the human diet. Taking advantage of the unique properties of microbes is one of the most promising ways to achieve inexpensive and sustainable approaches to improving productivity. The importance of microorganisms, including bacteria and yeasts, in food formulations and production systems to meet the food supply demand of the growing population, cannot be underestimated. Microorganisms can play an important role in increasing food security by promoting agricultural plant and animal biotechnological food production. Production of agricultural plants and animals is greatly influenced by the microorganisms that are associated with them. Fermentation technologies using beneficial microorganisms can also play an important role in ensuring food security through improved food preservation and production of fermented food products.

Table 1: A list of some microorganisms used in the production of fermented foods.

<table>
<thead>
<tr>
<th>Microorganism Used in fermentation of</th>
<th>Microorganism</th>
<th>Type of fermented food</th>
<th>Used in fermentation of</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Acetobacter fabarum</em></td>
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<td>chocolate</td>
<td></td>
</tr>
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<td><em>Acetobacter pasteurianus</em></td>
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<td>coffee</td>
<td></td>
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<tr>
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<td></td>
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<td>bacterium</td>
<td>vegetables</td>
<td></td>
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<td>bacterium</td>
<td>vegetables</td>
<td></td>
</tr>
<tr>
<td><em>Bacillus subtilis</em></td>
<td>bacterium</td>
<td>natto</td>
<td></td>
</tr>
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<td>yogurt</td>
<td></td>
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<tr>
<td><em>Clostridium butyricum</em></td>
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<td>cheese</td>
<td></td>
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<td>cheese</td>
<td></td>
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<tr>
<td><em>Candida atenaria</em></td>
<td>fungus</td>
<td>kefir</td>
<td></td>
</tr>
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<td><em>Debaryomyces kloeckeri</em></td>
<td>fungus</td>
<td>Limburger cheese</td>
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<td><em>Dekkerabrukeiella</em></td>
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<td>beer</td>
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<td><em>Enterococcus faecalis</em></td>
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<td>soy sauce</td>
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<td><em>Enterococcus faecium</em></td>
<td>bacterium</td>
<td>Manchego cheese</td>
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<tr>
<td><em>Enterococcus faecium</em></td>
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<td>ham</td>
<td></td>
</tr>
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<td><em>Enterococcus faecium</em></td>
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<td>Idiazabal cheese</td>
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<td><em>Lactobacillus casei</em></td>
<td>bacterium</td>
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<td><em>Lactobacillus casei</em></td>
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<td></td>
</tr>
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<td><em>Lactobacillus casei</em></td>
<td>bacterium</td>
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<td><em>Lactobacillus johnsonii</em></td>
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<td>Parmigiano-Reggiano cheese</td>
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<td><em>Proteus vulgaris</em></td>
<td>bacterium</td>
<td>surface-ripened cheese</td>
<td></td>
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<td><em>Pseudomonas fluorescens</em></td>
<td>bacterium</td>
<td>yogurt</td>
<td></td>
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<tr>
<td><em>Tetragenococcus koreensis</em></td>
<td>bacterium</td>
<td>kinchhi</td>
<td></td>
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<tr>
<td><em>Yarrowia polonica</em></td>
<td>fungus</td>
<td>dairy</td>
<td></td>
</tr>
<tr>
<td><em>Zygoricularia floridina</em></td>
<td>fungus</td>
<td>kefir</td>
<td></td>
</tr>
<tr>
<td><em>Zymomonas mobilis</em></td>
<td>bacterium</td>
<td>palm drink</td>
<td></td>
</tr>
</tbody>
</table>
sic and applied research to better understand the mechanisms by which microbial communities influence plant and animal productivity as well as biotechnological food production. More discoveries are continuously being made and technological improvements are constantly designed, suggesting that the use of microbes in food production, and the benefits that come with their use, are not limited to what has been revealed to date. A microbe-mediated increase in global food security would be an outcome well worth the investigations and related investments that may go into them.

REFERENCES


20. Rodriguez A, Sanders IR. The role of community and population ecology in applying mycorrhizal fungi for improved food security. The ISME J. 2014. doi: 10.1038/ismej.2014.207


Application of Ultra Superheated Steam Technology (USST) to Food Grain Preservation at Ambient Temperature for Extended Periods of Time

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ABSTRACT

Food security has been of great concern in every nation irrespective of their developed or underdeveloped status. Post-harvest losses are common for almost all agricultural products; therefore, these commodities are a matter of concern for all nations. Super-heated steam drying is a drying technology where the drying takes place through direct contact between superheated steam and the product to be dried. This study was designed to determine the effectiveness of Ultra-superheated steam technology (USST) drying alone or USST drying followed by mixing with scallop powder (SP; 0.1%) to extend the shelf life of: 1) Peanuts; 2) Red wheat (small sized); 3) Broken maize kernels; 4) Mixed animal feed; and 5) Bengal gram/chickpea. It was observed that treatment with USST at 400 ºC or 500 ºC (actual contact temperature was 210 ºC and 250 ºC, respectively) for 15 seconds was sufficient to decontaminate the mold successfully. After 26 months of storage at room temperature, no such mold was evident visually compared to control samples, and the products appeared fresh. Furthermore, treatment with USST at 400 ºC or 500 ºC (actual contact temperature was 210 ºC and 250 ºC, respectively) for 15 seconds was sufficient to increase the shelf life of the food grains studied beyond three years under similar experimental conditions. However, the product did not appear fresh or attractive subsequent to the attachment of the SP powder. Increasing the USST temperature may further enhance the shelf life of the product. Therefore, these findings suggest that USST technology may extend the shelf life of food grain products. However, optimization of treatment time and temperature is required for food grains to be most efficiently stored.

KEYWORDS: Ultra-superheated steam technology (USST); Food grains; Preservation; Ambient temperature; Risk reduction; Food security.


INTRODUCTION

Post-harvest losses of agricultural commodities have been a problem for all developing countries, particularly those that are primary producers. In these countries, non-mechanized harvesting practices and traditional technologies are still primarily used. Because of these, the extent of post-harvest food commodity losses are alarming. In order to overcome food deficiencies, these countries have traditionally emphasized two lines of action, e.g., (a) reducing future demand by slowing population growth and (b) augmenting food supplies by increasing
production. But perhaps the third and most important option in this context - the reduction of post-harvest losses - has not been given proper consideration. In addition, no such suitable technology has been developed to reduce post-harvest losses or to extend the shelf life of agricultural products.1,2

As well, farmers and manufacturers want to produce products that are healthy, tasty and functional as possible. At the same time, they seek higher returns from low-cost production, without any concessions to food safety or product quality. They also want to minimize the environmental impact of their production systems while maintaining maximum flexibility within these systems.3,4

From ancient times, man has devised a number of ways to preserve food. In general, foods have been preserved by applying heat, cold, drying conditions, salt and fermentation techniques.5 Other advanced technologies for long-term storage are being developed, which may eliminate the extensive use of preservation chemicals. One such technology is the use of Ultra- superheated steam technology (USST), which is a modified version of a superheated steam technology.3

USST is a new, innovative technology that can be used to extend the shelf life of agricultural food products. Hausbrand introduced the idea of using Super-heated drying (SSD) at the beginning of the 20th century, however, it was not until the 1950’s that researchers examined the process more closely.6 Following the 1970’s oil crisis, a number of papers were published on the fundamental properties and applications of superheated steam drying.7 Conventional hot air drying is an energy-intensive operation which accounts for approximately 15% of industrial energy consumption in most industrialized countries.8 The recent modification to this process is described herein, making this an emergent technology with considerable advantages in energy savings, emissions reduction, fire and explosion prevention, and improved product quality.9

**Superheated Steam: New Innovative Technology for Agricultural Product Disinfections**

Superheated steam is steam that is heated to a temperature that is higher than the boiling point of water. If saturated steam is heated at constant pressure, its temperature will rise, producing superheated steam. The newly developed Ultra Super-heated steam technology (USST; FBI Co. Ltd., Tokyo) continuously generates gas that consists of steam-originated electron radicals, in large scale, over a short time period under ordinary atmospheric pressure, through a specially designed high frequency current IH (induction heating) technology. “Steam-originated radicals” refers to highly active radicals of unpaired electrons, such as OH radicals (OH-), Hydrogen peroxide (HOOH), superoxide-anion radical (O2-), and singlet oxygen (1O2). In addition, ionized gaseous particles (H+, H- and HO-), which are water vapour (H2O) molecules, are generated from steam at 300 °C~500 °C temperature by using eddy current energy under a specially designed high frequency current IH super-heating induction technology USST Apparatus. The use of traditional steam super-heating technology would require a very high-pressure vessel with extremely thick and heavy specially processed steel material, resulting in much higher machine-cost and a heavy/gigantic specification as well as the employment of a specially licensed machine-operator to generate the 500 °C super-heated steam. The USST is an oxygen free environment, which eliminates the possibility of systemic fire or explosion and could lead to improved product quality by the elimination of scorching. The heat generation mechanisms of USST are shown in Figure 1.

The objective of this study was to use USST technologies to reduce post-harvest losses of various agricultural commodities and to extend their shelf life at ambient temperature. The following agricultural products were studied: 1) Peanuts; 2) Red wheat (small sized); 3) Broken maize Kernels; 4) Mixed animal feed; and 6) Bengal gram/chickpea.

**METHODS AND MATERIALS**

**Sample Collection**

The following five samples were collected from different markets in Dhaka City, Bangladesh and used in this experiment. These samples were collected in sterilized Ziploc Bags and were transported to the Food Analysis and Research Laboratory, Center for Advanced Research in Sciences, University of Dhaka, and half of the samples were taken to the Research and Development Laboratory, JSP Inc. Ltd., Tokyo for USST treatments. In this study, low quality samples were chosen in the belief that if low quality products can be controlled, then good quality products can be controlled with less effort.

1) **Peanuts:** The worst quality rotten or damaged peanuts were purchased from the Kawran bazar market, Dhaka City, Bangladesh. These peanuts are usually thrown away or given to the poorest people.

2) **Red wheat (small size):** Red wheat (small sized) was pur-
chased from the Kawran bazar market, Dhaka City, Bangladesh. This small sized red wheat is usually used for flour production for low income people in Bangladesh.

3) Broken maize kernels: Broken Maize kernels were purchased from Nimtoli market, Dhaka City, Bangladesh. These broken maize kernels are generally used for poultry/fish feed production.

4) Mixed animal feed: Mixed animal feed was purchased from Nimtoli market, Dhaka City, Bangladesh. These mixed animal feeds are widely used in the poultry industry in Bangladesh.

5) Chickpeas: Bengal gram chickpeas were purchased from Nimtoli market, Dhaka City, Bangladesh. Bengal gram chickpeas are one of the cheapest sources of protein for the common people of south Asia.

Scallop Powder (SP)

Scallop powder is a novel biodegradable sanitizer that is obtained from the inner portion of the scallop (*Patinopecten yessoensis*) shell by baking it at 200 °C and then exposing it to excessive heat (1000 °C). After that, the shells are pulverized and passed through a micro sieve to obtain 5-15 µm particles of powder. This powder is said to have antibacterial and anti-fungal activity. As this powder is produced from natural sources, it does not pose a hazard to the environment, and it is biodegradable.10

Sample Treatment and Conditioning

The experiment was conducted on September 03, 2011, at the Research and Development Laboratory of JSP Inc., Ltd., Tokyo, Japan. All five samples were passed through the USST chamber at 400 °C or 500 °C for 15 seconds and stored at RT and sealed separately in polyethylene packages. The following five treatment categories were applied to each sample studied.

1. Control (no USST treatment); stored at RT in sealed polyethylene packages.

2. The samples were passed through the USST chamber at 500 °C for 15 seconds (actual contact temperature was 250 °C) and stored at RT in sealed polyethylene packages.

3. The samples were passed through the USST chamber at 400 °C for 15 seconds (actual contact temperature was 210 °C) and stored at RT in sealed polyethylene packages.

4. The samples were passed through the USST chamber at 500 °C for 15 seconds actual contact temperature was 250 °C) then mixed with SP (0.1%) and stored at RT in sealed polyethylene packages.

5. The samples were passed through the USST chamber at 400 °C for 15 seconds (actual contact temperature was 210 °C) then mixed with SP (0.1%) and stored at RT in sealed polyethylene packages.

After the experiment, a set of five treated and non-treated samples were kept at room temperature in the Japanese laboratory for future reference. Another set of treated and non-treated samples was transported back to the Dhaka laboratory and kept at room temperature for future reference.

RESULTS AND DISCUSSION

Peanuts

Peanuts are known by many other local names, such as earthnuts, ground nuts, goober peas, monkey nuts, pygmy nuts and pig nuts. Peanuts can be an important part of the diet, as they provide over thirty essential nutrients and phytonutrients.31 In South Asia, peanuts are generally consumed as a light snack. They are usually roasted and salted (sometimes with the addition of chilli powder), or they may be sold roasted in the pod at road side or boiled with salt. Peanuts may be contaminated with the mold *Aspergillus flavus*, which produces a carcinogenic substance called aflatoxin. Lower quality specimens, particularly where mold is evident, are more likely to be contaminated. The United States Department of Agriculture (USDA) tests every truckload of raw peanuts for aflatoxins; peanuts containing more than 20 parts per billion of aflatoxins are destroyed.12

In this study, after 26 months of storage at RT, mold development was evident visually in the control sample, as shown in Figure 2. The mold was confirmed to be *Aspergillus flavus*, which produces carcinogenic aflatoxins. However, treatment with USST at 400 °C (actual contact temperature was 210 °C) for 15 seconds successfully decontaminated the mold, and after 26 months of storage, no mold was visually evident, and the products appeared fresh (Figure 2). Treatment with USST at 400 °C (actual contact temperature was 210 °C) for 15 seconds, followed by mixture with SP powder (0.1%), increased the shelf life of the peanuts by more than three years under similar experimental conditions. However, peanuts with residual SP powder did not retain an attractive appearance (Figure 2).

Therefore, this study demonstrated that the USST technology alone or USST treatment followed by mixture with scallop powder could be useful in extending the shelf-life of peanuts at ambient temperature.

Red Wheat (Small Size)

Wheat is one of the first cereals known to have been domesticated, and the ability of wheat to self-pollinate greatly facilitated the selection of many distinct domesticated varieties. Wheat is the world’s most favored staple food, and it is grown on more than 240 million hectares, which is a larger area than for any other crop.13,14 There are many wheat diseases, mainly caused by fungi, bacteria, and viruses. Fungicides, used to pre-
Maize Kernels (Broken)

Maize harvesting is a highly mechanized process in the developed world, while it is still done manually in developing countries. Changes in the physical quality of the grain are often a result of mechanical harvesting, shelling and drying. Storage stability depends on the relative humidity of the interstitial gases, which is a function of both moisture content in the kernel and temperature. Light moisture content and low storage temperatures reduce the opportunity for deterioration and microbial growth. Aeration therefore becomes an important operation in maize storage as a means of keeping down the relative humidity of interstitial gases. Significant maize losses have been reported in tropical countries.16 Losses of up to 10% have been found, not including those losses caused by fungi, insects or rodents. If these were included, losses could increase to 30% in tropical humid areas or to 10 to 15% in temperate areas. Losses due to fungi (mainly Aspergillus and Penicillium) are important for both economic and health reasons because of aflatoxins and mycotoxins.16

The efficient conservation of maize, like that of other cereal grains and food legumes, depends basically on the ecological conditions of storage; the physical, chemical and biological characteristics of the grain, the storage period, and the type and functional characteristics of the storage facility.

In this study, the control sample deteriorated considerably, with mold development being evident within one month. Treatment with USST at 500 °C (actual contact temperature was 250 °C) for 15 seconds was initially successful at decontamination, however, a white mold was visually evident after four months of storage. However, treatment with USST at 400 °C and 500 °C (actual contact temperature was 210 °C and 250 °C, respectively) for 15 seconds followed by mixture with SP (0.1%) decontaminated the mold, and after 26 months of storage no mold was evident visually, and the products looked better as compared to the control sample (Figure 4). Therefore, this study demonstrated that the optimization of time and temperature is necessary to eliminate mold and extend the shelf life of maize kernels at ambient temperature.

Mixed Animal Feed

The chemical and nutritional constituents of animal feeds are important for livestock nutrition and growth, but they are only part of the animal feed matrix. From an ecological standpoint, harvested grains are not only ingredients for livestock diets, but they can act as substrate and transmission vectors for simple unicellular prokaryotic and eukaryotic organisms.17 Feeds may contain diverse microflora that are acquired from multiple environmental sources, including dust, soil, water, and insects. Feed materials may be contaminated at any time during their growth cycle, while being harvested, processed, stored or dispersed. The microflora found in feed materials come from a variety of ecological niches, such as the soil and the gastrointestinal tract, and they must adapt to the chemical and physical parameters inherent to the animal feed and feed components in...
order to survive and/or grow. The microbial diversity found in different feeds depends on the water activity, oxygen tension, pH and nutrient composition of the feed matrix, and microbial growth is dependent upon the moisture content of the feed material. Some microorganisms, primarily moulds, have adapted to conditions without free water, and these microbes can actively grow in stored grains. However, the majority of microorganisms must exercise various strategies to survive until there is sufficient water content to support microbial activity. Microorganisms can decrease grain value through nutritional changes, physical damage, or the production of toxins that are deleterious to animal health.

In this study, the control sample deteriorated appreciably, and mold development was evident visually within 25 days of storage at room temperature. However, treatment with USST at 500 °C (actual contact temperature was 250 °C) for 15 seconds effectively decontaminated the mold, and after 6 months of storage, no mold was visually evident. In addition, treatment with USST at 400 °C and 500 °C (actual contact temperature was 210...
°C and 250 °C, respectively) for 15 seconds followed by mixture with SP (0.1%) successfully decontaminated the mold. After 26 months of storage, no such mold was evident, but the product’s appearance was not attractive following mixture with SP powder (Figure 5).

Therefore, this study demonstrated that the USST technology alone, or the USST treatment followed by mixture with scallop powder, were useful in extending the shelf-life of mixed animal feed at ambient temperature.

**Bengal Gram/Chickpea**

Bengal gram is called Chickpea or Gram (*Cicer aritinum* L.) in South Asia. Bengal gram is a major pulse crop in Bangladesh, widely grown and consumed there for centuries. It is a protein-rich supplement to cereal-based diets, especially in poor and developing countries, where people are vegetarians or cannot afford animal protein. It offers the most practical means of eradicating protein malnutrition among vegetarian children and nursing mothers. Bengal gram, one of the cheapest sources of protein for the common people, is now increasingly becoming expensive and getting beyond the reach of a large portion of the population in Bangladesh and India. The share of Bengal gram production has been decreasing, particularly since the mid-sixties. Total production has been low due to poor productivity and inadequate post-harvest storage and processing facilities. Food grains are stored for varying lengths of time before consumption as food, feed or seed. These are likely to be spoiled in storage by biological agents such as insects, mites, rodents, microorganisms or by moisture. The extent of this damage varies with storage conditions and structure. Storage losses range from 20 to 30 percent, causing enormous losses not only to the farmers but also to the overall national agricultural production system.

In this study, a control sample without the addition of SP was not tested due to the unavailability of Bengal gram during the experiment. Treatment with USST at 500 °C for 15 seconds decontaminated the mold, and after 26 months of storage, no such mold was evident, and the products appeared fresh. In addition, treatment with USST at 400 °C for 15 seconds followed by mixture with SP (0.1%) extended the shelf-life of the Bengal gram for more than three years, with no mold being visually evident. However, the product did not appear to be fresh or attractive as a result of the attachment of SP powder (Figure 6). This finding also demonstrated that USST technology alone or USST treatment followed by mixture with the scallop powder could be useful in extending the shelf-life of Bengal gram/chickpea at ambient temperature.

**CONCLUSION**

This study demonstrated that Ultra-superheated steam (USST) alone or USST treatment followed by mixture with SP powder (0.1%) were both able to extend the shelf life of: 1) Peanuts; 2) Red wheat (small sized); 3) Broken maize kernels; 4) Mixed animal feed; and 5) Bengal gram/chickpea for more than 26 months at ambient temperature, depending on the particular food grain tested. Therefore, this finding suggests that USST technology can extend the shelf life of agricultural products.
however, optimization of treatment time and temperature is required for each food product.

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CONFLICTS OF INTEREST

There are no conflicts of interest in the content of the manuscript.

REFERENCES


2. WFP/DFID. Food security in Bangladesh, World Food Programme, Dhaka; 2005.


12. Hirano S, Shima T, Shimada T. Proportion of aflatoxin B1


Commentary: Food Fortification: African Countries Can Make More Progress

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ABSTRACT

Micronutrient malnutrition (MNM) is a major public health issue in the developed world, but it is even more important in low-income, developing countries. The main forms of MNM include vitamin A, iron or iodine deficiency, but folic acid, vitamin D, selenium and zinc deficiencies, although less recognized, are important as well. A lack of those micronutrients represents a major threat to the health and development of populations, particularly children and pregnant women. They account for 7.3 percent of the global burden of disease.

In Sub-Saharan Africa where the prevalence of malaria, HIV, diarrhoea diseases and other infectious conditions is high, MNM increases their severity and has a high health impact on children and pregnant women. In Africa, the prevalence of anaemia in pregnant women is 52% percent and is a major factor that contributes to high maternal mortality rates. Vitamin D deficiency, rickets, osteomalacia and thyroid deficiency are highly prevalent chronic conditions in low income developing countries.

For many years, food fortification has proven to be the most cost effective means to prevent MNM. In recent years, many African countries have adopted mandatory fortification schemes. In 2002, Nigeria successfully mandated a salt iodization program and the fortification of maize and cooking oil with vitamin A, and sugar and flour with iron. The Tanzanian government passed mandatory food fortification legislation in July 2011, and it provides a tax exemption for imported premix for its national fortification program. Such efforts by African countries are playing a vital role in addressing MNM in Africa. More effort and support are needed to ensure that these programs are implemented successfully to effectively reduce MNM.

KEYWORDS: Food fortification; Micronutrient malnutrition (MNM); Folic acid; Vitamin D; Vitamin B12; Deficiency.

ABBREVIATIONS: MNM: Micronutrient malnutrition; DALYs: Disability-adjusted life years; VAD: Vitamin A Deficiency.

INTRODUCTION

This paper is written from the perspective of an African doctor with experience working in clinical and public health care and from that of a long experienced public health professional. The following commentary is, thus, addressed to policy makers and international donors interested in advancing the health of the African population. In Africa, malnutrition affects all age groups, but young children, women of reproductive age and the elderly tend to be among those most at risk of developing micronutrient deficiencies. For decades, considerable effort has been made to curb this “silent hunger”. In recent years, a number of African countries have initiated food fortification programs, which have proven to be cost effective in addressing...
the issue of food security. For example, in 2002, Nigeria successfully instituted a mandatory salt iodisation program, and it also began to fortify maize and cooking oil with vitamin A, and sugar and flour with iron.\textsuperscript{1,3} This established it as one of the first countries in Africa to embrace food fortification. A situational analysis two decades later showed that regulatory monitoring is requisite to ensure that fortification reaches it maximum potential.\textsuperscript{4}

Micronutrient malnutrition (MNM) is widespread in industrialized nations, but more so in low income, developing regions of the world.\textsuperscript{5,6} Fortification is a means to increase the content of essential micronutrients in basic foods; i.e., vitamins and minerals (including trace elements), so as to improve the nutritional quality of the food supply. Food fortification has advanced considerably in Africa,\textsuperscript{2} and along with providing needed supplements to high risk groups, it provides public health benefits at a minimal cost and risk to the public.\textsuperscript{3}

In Africa, the three most common forms of MNM are iron, vitamin A, and iodine deficiency but other forms of MNM, including deficiencies of folic acid, vitamin D, selenium and zinc, are also important. Together, these affect at least one-third of the world’s population, the majority of which resides in developing countries.\textsuperscript{7} MNM, being a risk factor for many diseases, can contribute to high rates of morbidity and case fatality rates.\textsuperscript{5} It has been estimated that micronutrient deficiencies account for ~7.3 percent of the global burden of disease, with iron and vitamin A deficiency ranking among the fifteen leading causes of the global disease burden.\textsuperscript{5}

According to WHO mortality data, ~0.8 million deaths (1.5 percent of the total) can be attributed to the annual level of world iron deficiency, and a similar percentage of the world’s vitamin A deficiency.\textsuperscript{5} In terms of the effect on overall health, as expressed by the term “Disability-adjusted life years (DALY’s)”, iron-deficiency anaemia results in 25 million DALY’s lost (or 2.4 percent of the global total), vitamin A deficiency in 18 million DALY’s lost (or 1.8 percent of the global total), and iodine deficiency in 2.5 million DALY’s lost (or 0.2 percent of the global total).\textsuperscript{5} In Africa, vitamin A deficiency significantly increases the under-five years of age mortality and morbidity levels, while iron deficiency anaemia is responsible for an estimated 20 percent of all maternal mortality while also contributing to poor physical and mental development in children.\textsuperscript{7} Such deficiencies increase the mortality rate from diseases such as measles, diarrhoea diseases, malaria, tuberculosis, HIV/AIDS and others.\textsuperscript{7}

Food fortification can lead to relatively rapid improvement in the micronutrient status of a population, and at a very reasonable cost, especially if advantage is taken of existing technology and local distribution networks.\textsuperscript{7} This strategy has a long historical background. Iodised Salt has been used in the United States since the 1920’s, and just prior to the US entering World War II, the fortification of milk with vitamin D, salt with iodine, flour with iron, niacin and other B vitamins were entrenched in the US based on the country’s experience in combating pellagra.\textsuperscript{5} Niacin has been added to bread in the US since 1938, vitamin D began to be added to margarine in Denmark in the early 1950’s, and vitamins A and D were first added to Vanaspati (hydrogenated vegetable oil) in India in 1954.\textsuperscript{5} Folic acid is added to flour on a mandatory basis in over 60 countries to prevent neural tube birth defects.\textsuperscript{8}

The most widely used vehicles for fortification are among the most commonly consumed foods in Africa, including oils and fats, milk, sugar, rice, wheat flour and maize flour, with all of these reaching the vast majority of the population. The micronutrients that must be fortified and consumed daily are vitamins and minerals, in the form of trace elements, which means that they required in only small quantities for growth and development purposes (macronutrients are proteins, carbohydrates and fats).\textsuperscript{3} Food fortification is the most cost effective and affordable way to reduce micronutrient deficiency in Africa.\textsuperscript{5}

**TYPES OF FORTIFICATION**

Food fortification can take several forms. When we fortify foods that are widely consumed by the general population, it is called mass fortification.\textsuperscript{9,10} To fortify foods designed for specific population subgroups, such as complementary foods for young children or rations for displaced populations, it is referred to as targeted fortification; permitting food manufacturers to voluntarily fortify foods available in the market place, is termed market-driven fortification. An example of this type of fortification is breakfast cereal, however, these cereals are not commonly accessed by the low income majority that is most in need of essential trace elements.\textsuperscript{9}

**IMPORTANCE OF FOOD FORTIFICATION**

In 1981, Sir Nicholas Wald and colleagues at the United Kingdom’s Medical Research Council demonstrated in a randomized control trial that spina bifida and anencephaly (neural tube defects) were folate deficiency disorders.\textsuperscript{8} Many years later, we are aware that folic acid fortification has proven to be a huge success in preventing these conditions\textsuperscript{9} and that more than sixty countries had started flour folic acid fortification programs by 2013.\textsuperscript{5} However, there is still resistance to mandatory fortification, and relatively few European countries have adopted this practice, while all countries in the Americas and many others have done so. Birth defects are a major contributor to infant mortality and morbidity, requiring costly life-long medical care. The benefits of birth defect prevention through food fortification are potentially large, and food fortification can be a very cost-effective public health intervention.\textsuperscript{9}

Fortification has nearly a century long record of success and safety, and it has proven effective in the prevention of specific diseases, including birth defects.\textsuperscript{5} Understanding the pathophysiology and epidemiology of micronutrient deficiencies, and implementing successful methods of prevention, are
both vital for nutritional security in setting contemporary public health standards for folic acid, vitamin A, vitamin B complex, including vitamin B12, and vitamin D intake. If a food fortification delivery system is in place, it is feasible to fortify it with several micronutrients, making safe intervention relatively easy to implement, regulate and monitor. In this case, food fortification is a more cost effective and sustainable strategy than are others.

Advantages of Food Fortification

Food fortification has many benefits, since it utilizes staple foods consumed by a large segment of the population, it does not change the original product, it is technologically feasible, and fortification can easily be implemented in developing countries.

Life styles have changed considerably around the world over the last several years. There is inadequate exposure to sunlight among children, primarily because children spend less time outdoors than they did in previous decades. The widespread prevalence of vitamin D deficiency, even in sunny countries, is especially high among breast fed, dark skinned children and obese children and adults. Vitamin D deficiency is also widely prevalent in countries at low latitudes, where it was generally assumed that UV-B radiation was adequate enough to prevent vitamin D deficiency, and in industrialized countries, where vitamin D fortification of milk and margarine has been implemented for many years. Supplements for pregnant women and infants, along with milk or other commonly used manufactured foods, fortified with vitamin D, are the most effective and affordable way to prevent vitamin D deficiencies, including rickets and osteomalacia. Food fortification does not require people to alter their diet, thus, it is socially acceptable. The effect of fortification is rapid and covers a large part of the population without deleterious effects on taste, shelf life or the nutritional value of the food. Fortification is the most cost effective approach to prevent nutrient deficiencies. It can be introduced quickly through existing marketing and distribution channels, and the benefits are readily apparent. Apart from that, fortification will reach other high risk groups, such as the elderly. Through basic food fortification, we may be able to prevent neuro-tube defects due to folic acid deficiency, Vitamin A deficiency (vitamin A), rickets and osteomalacia (vitamin D), dental caries (fluoridation of drinking water in endemic areas), goitre and growth delays (iodization of salt) and ID anaemia (iron in salt or flour). All these conditions can be prevented in the most at risk groups of children and pregnant women.

Requirements for a Successful Food Fortification Program

In order to have a successful food fortification program, political leadership and support from the health professions, industry and the general public are vital. Political will is needed to legislate mandatory food fortification and to regulate the food industry, with adequate legislation to ensure adherence to agreed upon practices and to set standards for other voluntary fortification schemes. Recognizing that anti-fortification lobbyists and misinformation is widely distributed on the internet, well planned public information campaigns by the government and NGOs will be required to lobby for improved maternal and child health through fortification. Consumer acceptance is very important, and there should be no cultural objection to fortification. The key players should ensure availability of micronutrients in a sustainable way.

Key Players

The following key players needed to succeed in facilitating a functioning and sustained fortification program include: government policy makers, the food industry, public health officials, regulatory bodies, NGOs and international donors, and quality monitors, such as nutrition bodies and community involvement groups. Policy forums and community focus groups can help to promote public understanding of the importance of fortification and to participate in reporting progress. Public health professionals and policymakers in state and local governments, with the support of international agencies, have a moral responsibility to promote aggressive and well-supported national nutrition policies.

Criteria for Fortification

An obvious requirement is that the fortified food(s) need to be consumed in adequate amounts by a large proportion of the target individuals in a population, and it should not adversely affect the balance of other nutrients. It is also necessary to have access to, and to use, fortifiers that are well absorbed yet do not affect the taste and appearance properties of foods. In most cases, it is preferable to use food vehicles that are centrally processed, and to have the support of the food industry. Vehicles selected must be a part of the regular daily diet of the relevant segment of the population, the amount of nutrient added must provide an effective supplement for low consumers of the vehicle, and it should not be harmful to the consumer or cause any noticeable change in the taste, smell, appearance or consistency of the product.

SUPPLEMENTATION

Supplementation is another vital approach used to provide additional nutrients, as a key component of public health programs, such as maternal and child health. This requires a long-term commitment and excellent outreach programs. Supplementation is the term used to describe the provision of internationally recognized doses of micronutrients, usually in the form of pills, capsules or syrups. It has the advantage of being a viable means to supply an optimal amount of a specific nutrient or nutrients, in a highly absorbable form, and is often the fastest way to control deficiencies in individuals or population groups that have been identified as being deficient.
Fortification technology includes the dry mixing of foods, such as wheat and maize flour and their products, and the supplementation of liquid and powdered milk, beverage powders, breakfast cereals, cooking oils, rice and other widely used processed foods. As well, nutrients can be dissolved or added in liquid milk, drinks, fruit juices, bread, pastas, cookies, or sprayed on corn flakes and other processed foods that require cooking or extrusion steps that could destroy vitamin activity. They can also be dissolved in oil for oily products, such as margarine, or added for sugar fortification. Vitamin A in powder form is absorbed onto the surface of sugar crystals when used with a vegetable oil or coated for foods like rice, where the vitamins sprayed over the grains must adhere to the food product to avoid losses when the grains are washed before cooking.

Monitoring Fortification for Quality and Impact

In order for fortification to have maximum health impact, quality measures must be monitored routinely, with results analyzed, and technical problems corrected. It is essential that the process include food control and program monitoring. Food control can be internal (industrial), external (regulatory) or commercial (households). Internal control is when public or commercial flour millers use procedures such as recording the use of premix and conducting spot tests to provide quality checks, while external control is when government authorities (such as food safety inspectors) test products at mills periodically to ensure that fortification meets the country’s specifications. Commercial control is when food safety inspectors check retail stores to be sure that the fortified product is in the marketplace. Monitoring involves using household and market surveys to confirm that fortified rice or food made with fortified flour is purchased, that people are consuming it, and that enough is eaten to have the desired effect. Impact monitoring checks if products are fortified at recommended nutrient levels and at least 80 percent of the population is consuming the products, so that countries may assess the impact of biological and clinical outcomes. Measures such as child growth patterns, anemia rates and iodine levels in the urine of pregnant women and schoolchildren are examples of vital biological monitoring. Data from routine demographic and health surveys or birth defect surveillance programs may be a valid indication of a fortification program’s impact.

Current Situation

Sub-Saharan Africa

Significant progress in food fortification is being achieved throughout Africa. In Sub-Saharan Africa, fortification has become an increasingly attractive option in recent years, so much so that planned programs have moved forward to the implementation phase more rapidly than previously thought possible. New low-cost tools are being developed to increase the ease of assessing micronutrient levels in fortified foods, thereby improving program monitoring and effectiveness in an ongoing and sustainable manner. More than 70 percent of the population of African countries with mandatory fortification and legislation is now estimated to be regularly consuming at least one fortified food staple daily. Zambia began a successful program of fortifying sugar with vitamin A in 1998. Continued support for food fortification is required to ensure scale-up throughout Africa. In South Africa, a significant decline in the prevalence of NTDs of 30.5 percent was observed, from 1.41 to 0.98 per 1,000 births (RR 5.69; 95 percent CI: 0.49-0.98; p 5.0379) following folic acid fortification.

Figure 1: Countries (N=53) with regulations for fortification of wheat flour with folic acid, by program status - worldwide, June 2010.

Case Report - Tanzania

In Tanzania, vitamin and mineral deficiency pose a severe health problem, contributing to the heavy burden of disease and disability as well as exacting a heavy economic toll. In April 1994, the national salt iodization program was officially inaugurated, which led to the availability of iodized salt in households. Availability of iodized salt subsequently increased from nearly zero in the 1980’s to a sufficiency level of more than 90 percent. Total goitre prevalence decreased from 25 percent in the 1980’s to 7 percent in 2004. In addition, iodized oil capsules have been distributed to ~5 million persons 1-45 years of age in severely endemic areas. The WHO classifies Vitamin A Deficiency (VAD) in Tanzania as a clinical and public health problem. Countrywide, an estimated 10,000 children are likely to suffer from VAD-related blindness at any given time.

The success of Tanzania in improving food fortification is partly due to improved community based programs with strong community participation. But the government has also been a contributing factor, with an announcement of mandatory food-fortification legislation in July 2011, and enforcement beginning in May 2013. The government provides a tax exemption for imported premix for the national fortification program.
CHALLENGES AND THE WAY FORWARD

Apart from these successes, food fortification faces a number of challenges which must be addressed. Among these are the cost of fortification, a lack of dietary diversification, the presence of natural anti-nutrient (i.e., phytates and tannins), disease and poor health due to AIDS, malaria and intestinal parasites, low utilization rates in large mills and a general lack of education.7

The benefits, safety and cost effectiveness of food fortification have been demonstrated globally, hence, more effort needs to be expended to ensure that all countries adopt mandatory food fortification programs to reduce the burden of various diseases that especially effect children and pregnant women.28 To achieve this in Africa, a number of priority activities are required, including harmonized fortification standards, strengthened quality management systems and capacities, dedicated and coordinated leadership and oversight of fortification programs, fortification coverage assessments, fortification labelling, and continued advocacy and monitoring.2,29 Home fortification has some advantages, and evidence in support of the efficacy of home fortification is building, as countries like South Africa and Malawi have shown certain degrees of success with this approach.30,31 One review demonstrated that home fortification with MNP reduced anaemia rates by 31 percent (six trials, RR 0.69; 95 percent CI 0.60 to 0.78) and iron deficiency by 51 percent (four trials, RR 0.49; 95 percent CI 0.35 to 0.67) in infants and young children when compared with no intervention or a placebo.32

RECOMMENDATIONS

The following recommendations are important for the success of food fortification, especially in developing countries:

- Food fortification should be recognized as a public health priority, no less important than universal vaccination programs.
- Government and NGO leadership are needed to enact legislation, funding and technical support for the mandatory and regulated voluntary fortification of basic foods to promote community awareness about the benefits of food fortification.5,33
- A multi-sectoral approach must be adopted in the establishment of any food fortification programme, encompassing participation of relevant governmental organizations, food industry, trade organizations, consumers, academic and research facilities, marketing specialists and any involved international organizations and agencies.34,35
- Ensure increased availability of fortified foods to the vulnerable groups of populations.26,34,37
- There should be appropriate fortification of foods used in food aid programmes, with donors being required to provide relevant nutritional information, particularly through adequate labeling.35

CONCLUSION

Food fortification is vital to national, community and individual health, therefore, we should adopt guidelines and regulations to ensure its proper implementation, to use processes that cause minimal losses, and to choose packaging materials that give maximum protection.16 Fortification by government mandate and regulation is essential, with cooperation from the private sector, food manufacturers, and in the context of broader policies for poverty reduction, education and agricultural reform.5,33 It should be part of priority public health nutrition vital to the development of the nation, along with supplementation, for high risk groups and nutrition monitoring.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

REFERENCES


Post-Harvest Issues: Rethinking Technology for Value-Addition in Food Security and Food Sovereignty in Zimbabwe

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ABSTRACT

The purpose of this study was to identify a number of critical issues concerning and influencing food security in Zimbabwe. Embedded within this narrative is a critical concern for reducing food losses and enhancing value-addition. Special focus is put on the treatment of fresh produce, especially in rural areas—be it vegetables, fruits or grain. Preservation and safety of the product are important at both the household and market levels. This study used case studies from across rural and urban Zimbabwe to establish the pressing issues surrounding post-harvest management strategies. The study ascertained that Zimbabwe is naturally privileged with fertile soils which are suitable for agriculture, but food security is threatened after harvesting. The study produced an appreciation for the wide range of methods and structures, such as pole-earthed granaries and vegetable drying, that are used in Zimbabwe to gain food sovereignty. Nevertheless, it was established that these methods are not effective in reducing post-harvest losses, hence the need to introduce modern technologies that can supplement the traditional methods of reducing losses to enhance food security.

KEYWORDS: Post-harvest; Food security; Food sovereignty; Value-addition; Food-losses.

ABBRévIatIoNs: MDGs: Millennium Development Goals; UPA: Urban and Peri-urban Agriculture; FAO: Food and Agriculture Organisation.

INTRODUCtIoN

Approximately 80 percent of Zimbabwe’s total land area is made up of fertile agricultural land, yet it is quite ironic that Zimbabwe is struggling to feed itself despite its rich soils. The agricultural sector plays a key role in the overall development of the national economy. It is also the main source of food accessibility at the national level, and a prime source of food and income for most households. The Zimbabwean government and the private sector (e.g. Agribank) were in the past instrumental in providing capital and other inputs to farmers. Yet, current economic turmoil has affected the ability of these institutions to finance farmers. Agribank is reported to have received loan applications worth 29 million dollars, yet it could only allocate 15 million for onward lending. Hence, many farmers cannot invest in the new, advanced technology that is needed for the post-harvest handling of crops. Achieving food security, however, can be said to be based on the efforts and technology used to transport, store, process and value-add to harvested crops. Crops can deteriorate and become unfit for sale or human consumption unless preserved, processed and stored under suitable conditions. Poor transport facilities can also result in spoilage and subsequent food-borne illnesses. The intent of this study was to identify critical post-harvest strategies that can enhance food security in Zimbabwe. Attention was given to post-harvest loss reduction strategies through marketing, storage, processing, technology and transportation as well as value-addition to the products. The paper is structured in four major sections. The first sections tackles the theoretical and analytical issues for food security and food sovereignty as well as issues surrounding post-harvest management strate-
gies, such as transportation, storage and processing. The second section gives an analytical description of post-harvest issues that affect food security in Zimbabwe. This section is based on case studies from both rural and urban areas across the country. The third section discusses research results and matches them with theoretical issues to come up with recommended policy options. The final section concludes the paper.

THEORETICAL AND ANALYTICAL ISSUES

This section provides an outline of the key concepts that underpin this study. Key concepts such as food security, food sovereignty, marketing, transportation, processing technology and storage are discussed.

The Food and Agriculture Organization (FAO) of the United Nations defines food security as a condition where all people have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life at all times. Food security is also defined as access by all people at all times to enough food for an active, healthy life. The opposite of food security is food insecurity, which is defined by Chirimuuta and Mapolisa as an economic and social state of limited and uncertain access to adequate food at a household level. Food security is broad in scope and includes hunger, malnutrition and famine. Food security comprises numerous components, such as food access, food distribution, a stable food supply, and the use of food. Long-term food security depends on food sovereignty, which emphasizes those who produce food and care for the natural environment.

Food sovereignty is an essential precondition for the existence of food security.

Edelman defines food sovereignty as national food security, which is derived from the local production of food. La Via Campesina has defined food sovereignty as “the right of each nation to maintain and develop its own capacity to produce its basic foods, respecting cultural and productive diversity”. Advocates for food sovereignty argue that local people should secure control over natural productive resources, possess a right to land, utilize and protect their indigenous knowledge and cultural identity. These aspects of food sovereignty promote food security by taking advantage of locally tapped riches and technology in post-harvest management strategies. Food sovereignty also helps to create local markets while offering income security.

It emerged from the Nyeleni Food Sovereignty Forum, held in 2007, that the aim of food sovereignty is to guarantee and protect people’s space, ability and right to define their own models of food production, distribution and consumption, with the objective being to advance local people’s nutritional status, incomes, economies, ecologies and culture. Food sovereignty is also believed to be a foundation for the promotion of democracy and greater citizen participation. This at a larger scale respects the voices of the poor and marginalized groups in society, which are usually women and children.

Claeys laments that despite the fact that food sovereignty has the potential to meet current and future human food needs and ecological protection, two processes endanger it. The first process is the globalization of world trade, which has created an opportunity for a few transnational companies to gain a monopoly over different food chain linkages. This undermines the capacity of local people to be self-sufficient and achieve self-determination. The second threat lies in the current modernist development agenda, which is supported by the Millennium Development Goals (MDGs). Food sovereignty is hindered by the first MDG, which aims at eradicating extreme poverty and hunger and the third one which aims to promote gender equality and empowerment of women. These two MDGs advocate for the reduction of the number of people engaged in food production by encouraging them to get jobs in the largely urban-based manufacturing and service sectors. Yet, there is a pressing demand for agricultural produce to enhance food security. There is a need to facilitate the marketing of the produce so that it reaches consumers inadequate quantities and of acceptable quality.

In general, marketing is a human activity that is directed at satisfying needs and wants through an exchange process. In agriculture, marketing refers to the process of providing agricultural produce to consumers. Marketing is a broad concept that includes features such as transportation, storage, packaging and supply. Marketing ensures that there is efficient processing and packaging of produce, preparation of marketing facilities and storage, and the facilitation of transportation to the markets. Growers can produce large quantities of good-quality harvest, but if they do not have a reliable, swift, and equitable means of getting such commodities to the consumer, losses will be extensive and food insecurity is inevitable. The major problem that affects the marketing of agricultural produce in Zimbabwe is the lack of improvement in terms of facilities and sanitation in the market stalls. Market places such as Mbare Musika in Harare are overcrowded, unsanitary and short of adequate facilities for loading, unloading and the storing of produce. Basically, the first step after crop harvest in marketing is the processing of the farm produce.

Crop processing is an essential step in converting harvested agricultural products into consumable, valuable and saleable products. Processing readies crops for storage, for preservation for future consumption, and for immediate marketing. Good crop processing and preservation methods minimize food losses and keeps food safe for consumption and sale. However, this also depends on good storage technologies. Technology plays a very critical role in ensuring food security. Post-harvest activities such as the harvesting itself, processing, packaging, storage and sales all depend on adequate and advanced technologies. However, the major challenge in developing countries is that most of the tools are neither manufactured locally nor imported in sufficient quantity to meet demand. In many developing countries, some good facilities are out of order or not functioning properly due to a lack of maintenance and the
unavailability of spare parts. Advanced transport networks and facilities, such as refrigerated vans, are also an essential component of post-harvest technologies. In developing countries where there is poor road infrastructure, production should be maintained as close to the major population centres as possible to minimize transportation costs. Crop storage technologies used across Africa vary according to the scale of the operation or the level of production. Food producers use both traditional and modern methods and structures, for drying, temperature control and atmospheric control. However, traditional methods such as pole structures and woven baskets are now being refigured as being inadequate in offering protection from insects. Developing countries such as Nigeria have problems in accessing appropriate storage technology, and this has resulted in a considerable waste of agricultural output and, consequently, considerable losses to its national economy. Zimbabwe has only one rainy season from October to March, and food is grown during this period. The food is expected to feed people until the next harvest season. This implies that there is a strong need to have good storage facilities which do not impinge on food quality and quantity. Grain storage structures help to protect against crop losses from insects, rodents, moulds, theft and fire.

STUDY DESIGN AND METHODS

The following is a case study by design, and it is qualitative in its approach. We engage in both rural and urban cases in order to unravel the post-harvest issues in these circumstances. Qualitative methods of data collection were employed in developing the argument for this paper. Such methods include documentary review. Data were well analyzed using textual analysis, discourse analysis and thematic analysis to determine which issues are common across different areas in rural and urban Zimbabwe.

RESULTS

Post Harvest Management Issues in Rural and Urban Areas of Zimbabwe

This section provides an analytical description of post-harvest issues that affect food security in Zimbabwe. Farmers in rural areas and in peri-urban areas produce grain, especially maize, as a means to enhance food security. The grain is preserved and stored to meet human food needs until the next harvest. However, the food is lost through the inferior post-harvest management strategies that are used. Horticulture is another form of farming that is practiced, especially in urban areas, with the aim being to eradicate poverty through income generation. Post-harvest issues remain critical in this type of farming. There is a lack of institutional support services, poor road networks, a lack of storage space and limited access to reliable markets.

Grain Post-Harvest Management Strategies in Rural Zimbabwe

Maize is the staple food in Zimbabwe, and it is widely grown across the country. Areas in agro-ecological region five, such as Masvingo and Chiredzi, receive rainfall of less than 650 mm/year, and it is highly erratic. This region is unsuitable for crop production, but local people still produce maize, millet and sorghum for their food security. Millet and sorghum are, however, the best crop alternatives, as they can withstand the low rainfall and high temperatures that are indigenous to this region. The maize, sorghum and millet that the country as a whole depends on are produced by communal and small-scale farmers who have very limited access to the advanced technologies needed to enhance value-addition for food security. Large-scale commercial farmers dominantly produce cash crops such as tobacco and cotton. They also depend on small-scale farmers for their own food security. The communal farmers use traditional post-harvest management systems.

Indigenous knowledge and the use of vernacular materials is very common in Zimbabwe’s rural post-harvest processes. This has largely contributed to the low levels of cereals that are grown and the lack of adequate income to acquire advanced technologies. Crop harvesting is mostly done manually, and it takes more time than necessary. The harvesting and drying techniques employed make the farm produce more prone to thieves. For instance, maize can be stacked in small pyramids and left to dry in the fields before de-husking can occur, and the corn ears can be ferried to the homesteads. On the other hand, maize plants can be left standing to dry completely before they remove the cobs and leave the maize stalks in the field. This method is encouraged, as it promotes conservation agriculture. Conservation agriculture hinges on minimum soil disturbance, mulching of the soil, and promotion of crop rotation, with the ultimate goal being to improve soil fertility.

After harvesting and drying, pesticides are applied to the grain before it is stored in plastic bags or sacks. The pesticides applied should be capable of protecting the grain from insects until they are ready for consumption. In rural areas, generally the same facility is used to store all grains, but in different containers or compartments. The traditional pole and earth structures (Plate 1) and woven basket structures (Plate 2) are the most commonly used granary structures in rural Zimbabwe. The base of the granary is raised off the ground to prevent animals, such as rats and mice, from eating the grain. The raised base also keeps the grain away from wet ground and facilitates ventilation. Poles alone or poles resting on rocks, as in Plate 1, support the granary. The granary is built with a removable thatched roof, which has a large overhang to protect the mud walls from rain. The interior of the pole earthed granary is cleaned and plastered with fresh cow dung before loading fresh grain. Cow dung is the best local material, as it is believed to have insect repellent properties. If resources permit, the walls and the floors can be flushed with an insecticide before loading the granary, as a supplement to cow dung. However, these granaries are slowly vanishing due mainly to a shortage of the appropriate construction materials, which itself is a result of deforestation. Termites also damage the timber used. Efforts at modernization have led to the rejec-
tion of the use of local and traditional methods. Nevertheless, woven basket structures are still commonly used in some areas that maintain strong traditional practices, such as in the Zambezi Valley and in North Eastern Zimbabwe.

Due to difficulties faced in accessing hardwood supply for the construction of traditional granaries, some farmers are now adopting the use of metal silos. Smallholder farmers are using these silos, with the added advantage that rodents and termites do not attack them. FAO in Zimbabwe implemented a pilot project from June 2010 to July 2011 in the districts of Guruve and Gokwe South. FAO trained local builders and local tin-smiths on the construction of improved brick granary and metallic silos. The aim of the project was to reduce post-harvest crop losses through improved post-harvest management practices in order to improve food security at the household level. The project promoted the construction of brick granaries and metallic silos (plate 3) which are much more effective for preserving the grain than more traditional storage structures.

The project empowered local farmers by giving them technical knowledge and skills on effective post-harvest management strategies. Farmers in Gokwe learned improved methods of drying and treating the grain before storing it in either metallic silos or the brick granary. Drying and treating grain before storage prevents the grain from moulding or caking while in storage. By October 2011, the quality of grain was still good, with no signs of pest infestation. The main challenge for the project was the lack of local construction materials. Gokwe South has loamy sandy soils which are not effective for making bricks.

Horticulture Post-Harvest Management Strategies in rural Zimbabwe

Horticulture is the science and art involved in the cultivation, processing and marketing of ornamental plants, flowers, turf, vegetables and fruits. In Zimbabwe and other developing countries, small-scale fruit and vegetable production plays an important role in income generation, poverty alleviation and in improving the nutrition and livelihood of the rural population. Just as it is in the case of grain, the horticultural sector suffers greatly from post-harvest losses. Post-harvest losses in fruits and vegetables can occur in terms of income, quantity, quality, nutritional value and aesthetic appeal, which affect market value.

After Zimbabwe gained independence, many people were involved in the call from the government to support and improve rural livelihoods. Rural capacity building programmes such as the European Union’s Lome Convention funding programme were implemented in rural areas to promote small-scale commercial farming and increase household incomes and food security. The European Union’s Lome Convention Funding Programme started supporting Small-scale Coffee and Fruit projects in Manicaland province from 1982. The projects promoted small-scale commercial production, value-addition and the marketing of coffee and fruits in Hondo and Rusitu Valleys. Despite
all these efforts, the small-scale farmers are still facing post-harvest challenges that result in both quality and quantity losses. The losses are attributed to poor post-harvest management of the fruits, especially at peak production, since they mature almost at the same time, causing seasonal gluts. Oranges are also perishable, and a lack of adequate storage facilities causes considerable losses.

In a study conducted by Musasa, et al., it was found that >40 percent of the mature fruit from the Rusitu citrus farmers are lost in the orchard and during temporary storage. A lack of pesticides, poor production practices due to lack of knowledge, poor storage facilities and poor physical infrastructure, such as access roads, transportation and communication, are the major causes of post-harvest losses. The small-scale farmers store their oranges under tree shades waiting for buyers, mostly intermediaries known as makoronyera, to purchase and supply to large-scale fruit juice producers elsewhere. Storage of oranges under tree shades exposes the fruit to adverse climatic conditions such as fluctuations in temperature and humidity, leading to deterioration in quality and consequent low market value. From this analysis, it is clear that local producers do not have the capacity to participate fully in the orange value-chain. Farmers only produce for family consumption and sell to local markets; hence, they lose considerable potential income.

Rolle argues that horticulture post-harvest losses can be attributed to rough handling, untimely harvesting, a lack of appropriate harvesting tools, inadequate field sorting, grading and packing protocols for commodities, poor transportation infrastructure, a lack of appropriate transport systems, and a lack of refrigerated transportation vehicles. However, post-harvest damage to bananas decreased significantly in Chipinge when a private company, Matanuska, invested in modern production technologies, such as handling facilities and pack sheds. The farmers were also equipped with a tractor to deliver the product to pack sheds and specialized trucks that could transport the product to the market.

Fruit and vegetable processing is largely influenced by two factors. The first is to promote food security in rural areas. Since Zimbabwe has only one rainy season, there is a need to preserve food produced until harvest the next season. For instance, donors who were engaged in the Musami area of Murehwa introduced communal drying technology to local people to enhance food security at the village level. The traditional technique of sun-drying leafy green vegetables is the most common in Zimbabwe and has been passed down from generation to generation from an early time. This technique enables households to access vegetables throughout the year. Drying of fruit and vegetable is also a preferred method to preserve foodstuffs to be used as raw material in other food products. For instance, both dried vegetables and fruits can be pounded into a powder and used to make soup, or the powder can be added to flour for cakes. The second drive in fruit and vegetable processing is to eradicate poverty through income generation. Processing adds value to fresh fruits and vegetables, thus permitting producers to generate income from locally available resources that are highly perishable. In this sense, processing becomes a market-oriented activity focused on increasing returns to producers while reducing losses.

Given the huge losses that fruit producers often encounter during temporary storage, some farmers have developed innovative ideas on how to process and add value to low quality fruits. Small-scale commercial farms, such as Golden Harvest and Froggy Farm, make jam as a way to reduce post-harvest losses. The marketing of fresh produce generates more sales revenue when compared to selling processed fruits, hence, processing is a secondary activity that adds value to second and third grade fruit, which may be unacceptable to the fresh produce market. Companies such as Cairns Foods Limited buy second and third grade fruits but do not give a rewarding price for these inferior products, so domestic processing increases the farmers’ potential returns to lower grade fruit. Other processors, such as the Rusitu Valley Jam Canners Co-op, process jam due to the constraints they face when marketing fresh produce. Poor road networks, deficiencies in transport and high costs make it difficult for farmers in Rusitu to access outside markets, resulting in insignificant losses of fresh produce.

Post-Harvest Management Strategies in Urban Zimbabwe

Urban and Peri-urban Agriculture (UPA) in Zimbabwe is practiced in two ways, either as onsite or off-site. On-site agriculture refers to agricultural activities that take place in a residential property while off-site agriculture refers to agriculture that takes place in open spaces as well as in the peri-urban areas. On-site agriculture is usually focused on perishable and high-value horticultural products, such as green vegetables, mushrooms, herbs, eggs, poultry and tomatoes that can be grown in confined spaces. The scale of UPA ranges from purely subsistence-oriented, small-scale semi-commercial gardeners and livestock keepers, to medium- and large-scale commercial endeavours. On the other hand, offsite agriculture usually consists of maize production for family consumption while others also sell surplus grain in the market to increase their income.

Urban areas do not rely totally on the rainy season, except for off-site agriculture. In this regard, there is little processing of vegetables produced at home, since there is no need to preserve for the next season. Mature crops are consumed soon after harvest, and some are sold immediately. Urban vegetable growers do not need storage space, since they harvest and sell them immediately. This gives urban production a niche against their fellow vegetable producers, who are based in rural areas. The drying methods used to preserve food by urban producers are identical to those used in rural areas, but the reasons for this differ. In rural areas, farmers store the vegetables until the next harvest, while in urban areas, vegetable producers dry the vegetables by choice for consumption. On the other hand, maize production is seasonal, and the produce must be...
stored and treated to meet the requisite quantity and quality until the next season. The post-harvest management strategies used in urban areas are basically the same as the strategies used in rural areas. The major difference is in storage structures. There are no household granaries in urban areas, rather, they use ordinary living rooms for this purpose.

There are also large-scale horticultural farmers in urban areas, and especially in Harare, Bulawayo and Mutare. The farmers mainly produce mushrooms, flowers and herbs. The produce is sold locally by the smaller farmers, while large-scale commercial farmers export their produce worldwide. The problem with local markets is that local supermarkets and retailers prefer importing horticultural products from South Africa regardless of the fact that the products will be readily available from local farmers. Retailers import farm products that include beetroot, grapes, peaches, frozen vegetables, carrots, bananas, cucumbers, peaches, plums, and even fruit juices. Local horticulture farmers and traders are failing to find markets for their produce, since local retailers import the same products elsewhere. This leads to post-harvest losses as farmers end up throwing their vegetables away after failing to secure markets, hence, threatening food security and income generation. Chiutsi reiterates that the problem lies with the policy makers who allow imports into the country. This policy is an abject failure, and it has opened the country to the importation of foreign goods.

Poultry production has gained popularity in recent years as a type of urban agriculture. Poultry gained recognition because of escalating prices for beef and pork, with more consumers resorting to poultry and poultry products due to its relatively low pricing. Urban residents have ventured into poultry production, and they sell their chickens to fellow residents. Some have the privilege to supply large supermarkets and fast food outlets, such as Chicken Inn. However, poultry farmers face numerous challenges once the birds are ready to sell. The major challenge is a lack of access to reliable markets as well as electrical failures. These failures cause severe losses, as it affects refrigeration storage facilities.

**DISCUSSION AND OPTIONS**

This study revealed that many loopholes are affecting the attainment of food security in Zimbabwe. The current level of post-harvest management that is being practiced in the country both in urban and in rural areas is not adequate to secure the country’s food needs. The use of traditional storage technology has many problems, including mould development and the failure to regulate temperature and moisture. In this regard, there is a need for advanced storage facilities, such as metal silos, which efficiently reduce pathogen losses in grain. Since this technology is expensive and beyond the reach of many communal farmers in Zimbabwe, who encompass the bulk of the national food provid-

**Table 1:** A summary of emerging post-harvest issues in Zimbabwe.

<table>
<thead>
<tr>
<th>Operation/ Activity</th>
<th>Current methods</th>
<th>Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvesting</td>
<td>- picking</td>
<td>- rough handling</td>
</tr>
<tr>
<td></td>
<td>- handling</td>
<td>- lack of appropriate harvesting tools, equipment and harvest containers</td>
</tr>
<tr>
<td>Processing</td>
<td>- sun drying</td>
<td>- inadequate field sorting, grading and packing protocols</td>
</tr>
<tr>
<td></td>
<td>- shelling/threshing</td>
<td>- lack of hygiene</td>
</tr>
<tr>
<td></td>
<td>- sorting/grading</td>
<td>- lack of adequate processing technologies</td>
</tr>
<tr>
<td></td>
<td>- packaging</td>
<td></td>
</tr>
<tr>
<td>Storage</td>
<td>- pole-earth granaries</td>
<td>- poor temperature conditions and sanitation of the storage facilities</td>
</tr>
<tr>
<td></td>
<td>- general/living rooms</td>
<td>- lack of cold storage rooms</td>
</tr>
<tr>
<td></td>
<td>- tree shades</td>
<td>- intensive electricity power cuts</td>
</tr>
<tr>
<td>Marketing</td>
<td>- neighbourhood markets</td>
<td>- poor road infrastructure</td>
</tr>
<tr>
<td></td>
<td>- supply to retail stores</td>
<td>- limited market information</td>
</tr>
<tr>
<td></td>
<td>- sell to food processors</td>
<td>- lack of marketing strategies</td>
</tr>
<tr>
<td></td>
<td>- sell to mediators</td>
<td>- inadequate and unsanitary market infrastructure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- inability to market products in domestic and international markets</td>
</tr>
</tbody>
</table>

*Source:* (Rolle, 2006)
ers, there is a need for the government and private sector institutions to assist these farmers financially in constructing metal silos. Projects such as that conducted in Gokwe and Guruve are sustainable, as they give relevant technical skills to local builders and tinsmiths on how to construct these silos even when the project executors have terminated the projects. The experience gained in Rusitu Valley indicated that there is a lack of access to markets for fresh produce, and it showed that there is a general lack of communication between producers and receivers as well as a lack of market information. Farmers should be well advised on market needs before they produce their crops so that they can minimize their post-harvest losses. Construction of good physical structures, such as road networks and communication channels facilitate marketing from producers to all participants in the value-chain, up to the consumer (Figure 1). In value-chain system development, farmers need to be linked to the needs of the consumers. This can be achieved if they work closely with traders and processors to produce the specific goods in specific quantities and quality as required by the end consumers.

Food security can be accomplished if there is continuous innovation, research and communication among the various participants in the value-chain. This will also increase the farmers’ market influence and profitability and consequently improve their livelihood. Marketing cooperatives can be useful among producers of major commodities in specific production areas. This facilitates the flow of market information, improved market access, and increased access to higher-value markets. Cooperatives also help small-scale and communal farmers to share advanced materials used for post-harvest crop management. The government and respective organizations should advocate for a deliberate policy that regulates the importation of products that can be produced locally. This will help to protect the rights of local producers to access retail markets and thus minimize the losses that occur when their produce is not sold.

CONCLUSION

This study has demonstrated that the traditional methods of post-harvest crop management that are used in Zimbabwe cause major losses in vegetable, fruit and grain production. Grain, which is normally the major source of food, goes through five post-harvest stages. These are: harvesting, drying, shelling, storage and marketing. Horticultural products are usually perishable, and they are consumed soon after harvest. A lack of advanced technology in terms of transportation systems, storage facilities and marketing services is the major cause of post-harvest food losses in Zimbabwe. This affects food security for the entire country. Food sovereignty is also a critical issue that needs to be incorporated into the concept of food security. Local knowledge and traditional practices, such as vegetable drying, have proven to be relatively efficient in enhancing food security. Nevertheless, there is a need to combine traditional post-harvest management strategies with new emerging technology in order
to minimize overall food losses.4,34

COMPETING INTEREST

The authors declare that they have no competing interests.

REFERENCES


7. La Via Campesina. Food is first and foremost a source of nutrition and only secondarily an item of trade; 1996: 3.


26. Mlambo BM. Facilitating the effective production and mar-
keting of processed food products by small-scale producers in Zimbabwe (Project R7485); 2002. Not published.


Inadequacies in Good Manufacturing Practices and High Health Risks are Still Problems in Food Production in Public Preschools and Daycares in Rio Branco, Acre, Western Brazilian Amazonia

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ABSTRACT

Background/Objectives: In Brazil, the National Program of School Feeding (PNAE), was created with the objective of meeting the nutritional needs of students, guaranteeing the adequate growth and development of children, and assuring quality sanitation of the food offered. With the intent to guarantee a high level of sanitation of the food offered in the educational field, Good Manufacturing Practices (GMPs) were also instituted. The objective of this study was to evaluate the GMPs employed to produce the food offered in the Rio Branco – AC school system’s daycares and pre-schools.

Methods: The study was undertaken in 15 schools and 6 public daycares, corresponding with 50% of the total number of schools that admit preschoolers. A “List of Verification of Good Practices in School Feeding and Nutrition” was employed, and a final score was obtained for each school, through which the school was classified by the degree of health risk that it presented.

Results: In the 21 schools studied, inadequacies in all analyzed criteria were observed. When classified according to general health risks, 81% of the schools presented moderate health risks and 19% presented high health risks. The most scrutinized criteria were “Controlled Temperature Equipment,” “Buildings and Installations,” “Processes and Production,” and “Sanitation of the Environment.” The main problems detected were related to inadequate sanitation of the hands (90.48%) on the part of the food handlers; the absence of mandatory Good Practices and Standard Operational Procedures Manual (POP) (100%), and the absence of fans in the production area (95.24%).

Conclusions: The main problems identified in the evaluated school feeding production units were related to inadequate physical unit structures and the incorrect handling of the foods on the part of those involved in the production process. Therefore, the importance of continued training about Good Fabrication Practices (BPFs), the presence of nutritionists in sufficient numbers during the production process, and a restructuring of the physical space within the food production units need to be highlighted.

KEYWORDS: School feeding; Health risk; Food production; Good manufacturing practices.

ABBREVIATIONS: GMPs: Good Manufacturing Practices; BPFs: Good Fabrication Practices; PNAE: National Program of School Feeding; BPF: Good Fabrication Practices; UAN: Alimentation and Nutrition Units; DTA: Diseases Transmitted by Food; PNAE: National Program of School Feeding.
INTRODUCTION

In Brazil, childhood education begins with daycare and preschool, covering children between the ages of 0 and 6 years of age. During this phase of life, the child is in the process of developing his or her motor and cognitive skills as well as forming proper feeding habits that will likely persist into adulthood.¹

In Brazil, the National Program of School Feeding (PNAE) was created in the 1950's,² and it is one of the oldest public policies in the country. Besides this, it is one of the largest school feeding programs in the world, both in number of students attending and in allocated resources.³

The program aims to meet the nutritional needs of students during their stay in the classroom, and to contribute to the growth, development and knowledge of the students, including the formation of good eating habits. City and state administrators at PNAE are responsible for assuring the correct acquisition, transport, and storage of raw materials, as well as the sanitary preparation of the meals.⁴

Good Fabrication Practices (BPF) were adopted to guarantee the quality and sanitation of the meals offered within the school environment. They relate to the products, processes, services and buildings involved in the production of food. The legislation concerning BPFs can be found in Ordinance SVS/MS #326, which food service organizations need to follow to be in compliance with the law.⁵

Kitchens designated for school food preparation, including distribution locations, should be structured and planned in accordance with BPF guidelines, with the goal being to guarantee sanitary conditions. The majority of kitchens in Brazilian public schools do not possess adequate facilities to handle food hygienically, from raw material reception to distribution, with cross contamination being a distinct possibility.⁶

The food produced in the school Alimentation and Nutrition Units (UAN) should have adequate nutritional value, meeting the nutritional needs of the appropriate age group, and they should have organoleptic appeal and be sanitary. Sanitation quality is an indispensable factor in the handling of food, because it is related to the promotion and maintenance of the student’s health.⁷

Insufficient sanitation control is a determining factor in the appearance of Diseases Transmitted by Food (DTA), caused mainly by contamination and bacterial growth in food. The age group of students that attends daycare and preschool needs greater attention in relation to sanitation control, since this group of individuals is more vulnerable to the development of DTAs.¹⁸⁻¹⁰

Knowing the extreme importance of verifying the preparatory conditions for school meals so that strategies can be created to guarantee a high level of sanitation, the objective of this study was to evaluate the GMPs of the school feeding programs offered in the city daycare and pre-school system of Rio Branco – Acre.

MATERIALS AND METHODS

This study was conducted in the children’s county school system of Rio Branco, capital of the state of Acre. The city is situated in the north of Brazil (latitude: 9°58’29’’; longitude: 69°48’36’’; altitude: 153 meters), in the administrative region of Lower Acre, and its population is approximately 364 thousand (Figure 1).

In the county, the National Program of School Feeding (PNAE) was instituted since its emergence on the national scale. County school feeding is responsible for 42 public schools of children’s education, attending to approximately 9,300 children. The present observational, descriptive, and cross temporal study investigated 21 schools (15 pre-schools and 6 daycares) that represent 50% of the total public schools that admit preschool age children from the county. The selection of the schools was determined by a simple random drawing.

The data were collected from the first semester of the year 2015. Adherence to good manufacturing practices was rendered through a “List of Verification of Good Practices in School Feeding and Nutrition,” with a basis on Brazilian legislations RDC 216/2004,¹¹ Resolution SS-196/1998 (SÃO PAULO, Brazil, 1998), Ordinance CVS 06/1999 (SÃO PAULO, Brazil, 1999), Ordinance 542/2006 (RIO GRANDE DO SUL, Brazil, 2006). This list contains basic aspects of production activities and their installations: storage, physical area of the kitchen and cafeteria, utensils, water supply, integrated control of vectors and urban pests, garbage, handlers, snack ingredients, production flow, handling and contamination.

The School Inspection Guide was applied to six cri-
teria: buildings and installations of the food preparation areas, temperature control equipment, handlers, reception, processes and productions, and environmental sanitation, and it was composed of 113 items with response options YES, NO, and NOT APPLICABLE. Each item on the verification list was attributed grades that varied from zero to eight, according to the degree of risk and importance to the security of the food (08 – for conditions/situations that permit the multiplication of microorganisms; 04 – for conditions/situations that permit the survival of microorganisms; 02 – for conditions/situations of cross contamination with direct contact with the food; 01 – for conditions/situations of cross contamination without direct contact with the food; 0 – for conditions/situations of no-compliance; NA – for conditions/situations that don’t apply to the observation).

Besides this, a weight (k, equal to 10, 15, 25, or 30) was assigned to each criterion according to the degree of risk and importance to the security of the food. For the calculation of each point obtained for the criterion on the verification list, the formula \( PB_x = (\sum x / P_x - \Sigma NA_x) k_x \), where: \( PB_x \) – score reached for the criterion \( X \) (1 to 6); \( \Sigma x \) – Sum of the grades obtained in the items of the criterion \( X \); \( P_x \) – Maximum score possible for the criterion \( X \); \( \Sigma NA_x \) – Sum of the grades of the non-applicable questions for the criterion; \( k_x \) – Weight attributed to criterion \( X \), was applied. After the calculation of the obtained score for each criterion (PB), the results were added together. A final score was obtained for each school (presented as %), and with this score as a base, the school was classified by criteria and by total score according to health risk: 0 to 25 - very high health risk; 26 to 50 - high health risk; 51 to 75 moderate health risk; 76 to 90 - low health risk; 91 to 100 very low health risk.

RESULTS

In the 21 schools studied, inadequacies were observed for criteria all analyzes. When classified according to general health risks, 81% of the schools presented a “moderate” health risk and 19% a “high” health risk. In stratifying the health risk by observation criteria, the schools remained in the “moderate” to “high risk” category, except under the “Reception” criterion (Table 1).

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Risk(%)</th>
<th>Classification of Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buildings and Installations</td>
<td>49.99</td>
<td>High</td>
</tr>
<tr>
<td>Temperature Control Equipment</td>
<td>35.89</td>
<td>High</td>
</tr>
<tr>
<td>Handlers</td>
<td>67.63</td>
<td>Moderate</td>
</tr>
<tr>
<td>Reception</td>
<td>92.38</td>
<td>Very Low</td>
</tr>
<tr>
<td>Processes and Production</td>
<td>46.94</td>
<td>High</td>
</tr>
<tr>
<td>Environmental Sanitation</td>
<td>47.79</td>
<td>High</td>
</tr>
</tbody>
</table>

Table 1: Distribution of risk classifications by criteria. Rio Branco – Acre, 2015.

Among the criteria evaluated under “Buildings and Installations of the Area of Food Preparation” (Table 2), only the constitution and state of conservation of the walls of the production area showed adequacy of more than 50%. In relation to the “Area of Storage in Ambient and Controlled Temperature,” the main items that did not conform were the protection of the inferior opening of the doors and windows and the temperature control of the equipment (Table 2).

In relation to the handlers, in 76.19% of the schools these handlers were not “Correctly uniformed”, 52.38% used adornments (“Absence of Accessories/Adornments”), and in all of the schools, collaborators who had not received food and nutritional safety training were present (All that participated in training involving Food Safety) (Table 2).

The criterion “Reception” was the one in which the schools were most in accordance to the legislation. In more than 90% of the establishments, the characteristics of “Integrity of packaging is verified” and “Expiration date is verified” were observed. (Table 3).

The criteria referring to “Processes and Productions” presented high non-adherence to the legislation. In 90.48% of the schools, the handlers sanitized their hands in an inadequate fashion (“Collaborators sanitise their hands appropriately”) and in 61.90% the same handlers disinfected vegetables and fruits in an incorrect way (“Legumes and vegetables are disinfected in an appropriate way”). None of the schools possessed the mandatory Good Practices and Standard Operations Manual (POP) (“Existence of Good Practices Manual accessible to the handlers”) (Table 3).

In relation to “Environmental Sanitation”, 66.67% of the schools disposed of waste in an inadequate way (“Waste disposed by correct methods and in adequate recipients”) and held the practice of sweeping a dry floor (“Existence of the practice of sweeping a dry floor in the production area”). All of the schools used sponges made from abrasive material that were not boiled daily (“Brushes and sponges are not made of abrasive materials”; “Dish sponges are boiled every day”). In 85.72% of the schools, the disinfection and drying of the utensils were done the wrong way (“Chemical disinfection of utensils and equipments done the correct way”; “Utensils and equipments are dried without the use of towels”). The existence of pests was evident in 76.19% of the pest and urban vectors (“Non-existence of evidences of rodents, cockroaches and insects”; “Existence of documents that prove the integrated control of vectors and pests”) (Table 3).

DISCUSSION

Among the activities developed by the managers of the public school feeding program in Rio Branco are the elaboration and execution of menus, the development of policies of alimentation and nutrition in the school environment, the nutritional evaluation of students, and training in food safety of the collaborators involved in the process of school feeding.

The program in the county relies on the presence of
<table>
<thead>
<tr>
<th>Item Evaluated</th>
<th>Yes</th>
<th>No</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>“Buildings and installations of the food preparation area”</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Satisfactory hygienic conditions in the surroundings</td>
<td>6</td>
<td>15</td>
<td>71.43</td>
</tr>
<tr>
<td>Hygiene and conservation of the floors and production areas</td>
<td>9</td>
<td>12</td>
<td>57.14</td>
</tr>
<tr>
<td>Adequacy of the constitution and the state of conservation of the walls</td>
<td>11</td>
<td>10</td>
<td>47.62</td>
</tr>
<tr>
<td>Doors of the productions areas possess automatic closing and protection of the inferior openings</td>
<td>-</td>
<td>21</td>
<td>100</td>
</tr>
<tr>
<td>Windows of the production area covered with screens</td>
<td>-</td>
<td>18</td>
<td>85.71</td>
</tr>
<tr>
<td>Lamps in the production area with security against accidental falls</td>
<td>-</td>
<td>21</td>
<td>100</td>
</tr>
<tr>
<td>Nonexistence of fans in the production area</td>
<td>1</td>
<td>20</td>
<td>95.24</td>
</tr>
<tr>
<td>Sink exclusive for the sanitation of hands</td>
<td>-</td>
<td>21</td>
<td>100</td>
</tr>
<tr>
<td><strong>“Storage Area in ambient and controlled temperatures”</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Door with automatic closing action and protection over the inferior openings</td>
<td>-</td>
<td>21</td>
<td>100</td>
</tr>
<tr>
<td>Windows/openings covered with millimetre screens</td>
<td>3</td>
<td>18</td>
<td>85.71</td>
</tr>
<tr>
<td>Shelves are washable and impermeable</td>
<td>6</td>
<td>15</td>
<td>71.43</td>
</tr>
<tr>
<td>Storage of the cleaning material in exclusive area</td>
<td>10</td>
<td>11</td>
<td>52.38</td>
</tr>
<tr>
<td>Sufficient refrigerator and freezers</td>
<td>19</td>
<td>2</td>
<td>9.52</td>
</tr>
<tr>
<td>Chambers/refrigerators are regulated in a way to keep food at the correct temperature</td>
<td>-</td>
<td>21</td>
<td>100</td>
</tr>
<tr>
<td>Accumulation of ice and obstruction of air diffusers in the refrigeration and freezing equipment</td>
<td>15</td>
<td>6</td>
<td>28.57</td>
</tr>
<tr>
<td><strong>“Handlers”</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correctly uniformed</td>
<td>5</td>
<td>16</td>
<td>76.19</td>
</tr>
<tr>
<td>Periodically renewed medical exams</td>
<td>11</td>
<td>3</td>
<td>14.28</td>
</tr>
<tr>
<td>Absence of Accessories/Adornments</td>
<td>10</td>
<td>11</td>
<td>52.38</td>
</tr>
<tr>
<td>All that participated in training involving Food Safety</td>
<td>-</td>
<td>21</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 2: Distribution of the items evaluated by the criteria of “buildings and installation in the area of the preparation of food”; “storage areas in ambient and controlled temperatures” and “handlers”. Rio Branco – Acre, 2015.
<table>
<thead>
<tr>
<th>Items Evaluated</th>
<th>Yes</th>
<th>No</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>“Reception”</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Characteristics of the food are verified</td>
<td>19</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Integrity of packaging is verified</td>
<td>19</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Expiration date is verified</td>
<td>20</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>“Processes and Productions”</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collaborators sanitise their hands appropriately</td>
<td>2</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Foods are taken from their boxes and are received at the time of storage</td>
<td>11</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Existence of products with expired dates in the storage area</td>
<td>3</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Existence of cardboard boxes in storage area under cold air</td>
<td>7</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Food genres are available in an appropriate form in the refrigeration</td>
<td>14</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Legumes and vegetables are disinfected in an appropriate way</td>
<td>7</td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td>Defrosting done the appropriate way</td>
<td>15</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Existence of Good Practices Manual accessible to the handlers</td>
<td>-</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Existence of the mandatory 04 POPs accessible to the handlers</td>
<td>-</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Foods in distribution do not go more than 2 hours from the end of preparation</td>
<td>15</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>until distribution</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>“Environmental Sanitation”</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waste disposed by correct methods and in adequate recipients</td>
<td>7</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Area of waste external, isolated or treated to avoid contamination</td>
<td>17</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Garbage removed daily or always when necessary</td>
<td>21</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Environmental sanitation done in an appropriate way</td>
<td>16</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Brushes and sponges are not made of abrasive materials</td>
<td>-</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Cleaning utensils of the handling area are different than the cleaning utensils</td>
<td>20</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>used for bathroom sanitation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Existence of the practice of sweeping a dry floor in the production area</td>
<td>14</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Chemical disinfection of utensils and equipments done the correct way</td>
<td>3</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Utensils are kept under protection</td>
<td>8</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Utensils and equipments are dried without the use of towels</td>
<td>3</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Non-disposable cleaning cloths are changed every 2 hours and sanitised the</td>
<td>2</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>correct way</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dish sponges are boiled every day</td>
<td>-</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Pest control is done by a third party company</td>
<td>20</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Nonexistence of evidences of rodents, cockroaches and insects</td>
<td>5</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Existence of documents that prove the integrated control of vectors and pests</td>
<td>3</td>
<td>18</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Distribution of the items evaluated by the criteria of “reception”; “processes and production” and “environmental sanitation”. Rio Branco – Acre, 2015.
just two responsible nutritional technicians, charged with the execution of the same. According to Resolution CFN #465/2010, this number of professionals is insufficient for the development of the activities of the program, because the same legislation specifies that the modality of children’s education (daycare and pre-school) should have one nutritionist for every 500 students or fraction therefore. In this way, the county should rely on approximately eighteen nutritionists to properly execute the PNAE.

Sidaner, Balahan and Burlandy affirmed in their study that, in 2010, 15% of Brazilian counties do not possess a nutritionist of professional stature due to a lack of resources and of professionals in the region.

In all alimentation and nutritional units (UAN) in the schools visited, nonconformities in all of the analyzed criteria were observed, indicative of potential contamination risks in the foods produced in those schools.

As to the building conditions, various non-conformities were observed, such as waste, objects in disuse, animals or insects and rodents in the surroundings of the UANs, and an absence of protection in the inferior openings and in screens in the windows and production areas. Similar results were observed by Oliveira, Brazil and Taddei, who cited greater inadequacies in terms of physical structures of the schools studied, including doors without baseboard protection and, additionally, windows without screens.

Irregularities in the floors and walls of the UANs were also verified. These same structures were neither impermeable nor washable and were not found in a good state of repair. A situation similar to this was observed by Silva, Germano and Germano in a study conducted in the public schools in the state of São Paulo, in which 50% of the schools presented floors and walls in poor condition.

According to RDC 216/2004, the lamps and lighting fixtures localized above the food preparation area should be protected against possible explosions and accidental falls. Following this resolution, the nonexistence of fans with airflow focused directly over the food must be guaranteed. None of the schools had lamps adorned with a security system against accidental falls, and only one of them guaranteed the absence of fans in the handling areas.

In accordance with RDC 216/2004, the sinks should be exclusively for the sanitation of hands, possess odorless liquid antiseptic soap, non-recycled paper towels or another hygienic and safe system of hand drying, and a paper collector that can be used without manual contact. Hand washing, if performed properly and with the necessary frequency, is one of the most important measures in diminishing the quantity of microorganisms that contact the food, reducing the chance of possible food contamination. There were no sinks exclusively for the collaborators to use for hand sanitation in the handling areas during food production, in any of the schools.

The largest non-conformity observed in the temperature controlled storage area was the absence of thermometers for temperature control in the refrigeration and freezing equipment, which made the guarantee of ideal food storage temperatures impossible to determine. According to Colombo, Oliveira and Silva, refrigerators must remain at a temperature of 5 °C or lower to reduce the speed of bacterial growth and the development of food borne diseases in the food. The ideal temperature for freezers, approximately 18 °C below zero or lower, halts bacterial growth, while even killing some pathogenic bacteria.

The lack of temperature control in refrigerators and freezers could contribute to the development of microorganisms due to inadequate storage temperatures, as well as the accumulation of ice and/or obstruction in these appliances. These conditions were verified through the application of the check-list.

The handlers of food are, for the most part, the main factor in food contamination, since they are in constant and direct contact with the food and many times do not practice the proper sanitation procedures. The correct application of the BPF provides a reduction in cross contamination by food handlers.

The uniforms used by the handlers should be adequate, complete and duly clean in order to avoid cross contamination. Handler’s shoes must be closed-toed, impermeable, and in good condition.

Adornments, such as rings, earrings, and bracelets, should not be used by handlers during work. This is due to the high probability of these adornments not being duly sanitized, presenting a danger of contamination; that they may come loose and fall into the preparations and that they may be risk factors to personal safety and to the integrity of the equipment and preparations. This demand was not being fulfilled in any of the schools.

It is important to emphasize the necessity of conducting regular medical examinations on the food handlers, since even those who appear healthy possess bacteria on the skin, and in the mouth, nose and intestinal tract, which can contaminate food.

In all of the schools, there were food handlers that had not gone through any kind of food safety training. According to Oliveira, Brazil and Taddei, one of the main problems in an institution’s food production unit is the absence of training for food handlers. It is necessary that food handlers participate in relevant training programs and courses so that they can better understand how to apply BPFs to insure that sanitary meals are produced and food borne diseases are not transmitted. The RDC 216/2004 determines that handlers be trained regularly in personal hygiene, hygienic handling of the foods, and in disease transmission by foods, and that the training be documented.
Machado, Monego and Campos concluded in their study that it is necessary to change the production management of the meals in order to reduce health risks, monitor the hygienic practices of the handlers during the production of food and train them “in a constructive manner”.

Among the duties of nutritionists responsible for PNAE, is the training of professionals that act directly in the execution of the program. In this way, it is the responsibility of the nutritionist to offer the necessary training, which will require the participation of the handlers.

In relation to the receipt of raw material, the legislation determines that its general conditions, packaging integrity and the temperature of the food that requires special storage conditions, be verified. The temperature of the food was not verified in any of the schools due to a lack of the specific equipment needed, which could result in the receipt of products at an incorrect storage temperature.

The correct sanitation of the hands on the part of the food handlers is one of the main requirements in the prevention of DTAs. The handlers should sanitize their hands in the following manner: wet the hands and forearms with water; wash them with neutral, odorless, liquid soap; wipe well and dry them with a non-recycled paper towel or through any other form of drying that does not permit the recontamination of the hands, always when arriving at work, after touching contaminated materials, after using the bathroom, and whenever else it is needed. In the study by Oliveira, Brazil and Taddei, it was observed that 87.5% of the food handlers did not use the correct hand washing technique.

The sanitation of vegetables and fruits should be by immersion in bleach, or other sanitizer, for a period of 10 to 15 minutes, favoring the reduction of pathogenic microorganisms, thus diminishing the health risk to the students. Oliveira, Brazil and Taddei found in their study that 80% of the evaluated daycares did not practice adequate procedures for food disinfection in the pre-preparation phase.

All food services should possess the Good Practices Manual and practice the standard operational procedures. These documents should be easily accessible to all those involved in food service, and they should be available to the sanitation authorities when solicited. None of the schools were in possession of the Good Practices Manual and none of the four mandatory Standard Operational Procedures (POP) (Sanitation of installations, equipments and furniture; integrated control of urban vectors and pests; Sanitation of the reservoir; Sanitation and health of the handlers) were accessible to the food handlers.

According to RDC n° 275/02, the Good Manufacturing Practices Manual should describe the operations that are done by the UAN, including at least the sanitation requisites of the building, the maintenance and sanitation of the installation, the equipment, and the utensils, the control of the water supply, the integrated control of urban vectors and pests, the control of the hygiene and health of the handlers, and the control and guarantee of the final product quality. The POPs can be annexed to the Good Manufacturing Practices Manual and should be monitored regularly to guarantee their purpose.

All establishments should post upright containers, easily cleanable, adorned with lids liftable without the use of hands for the ridding of waste. These units should be frequently collected and stored in locations isolated from the handling area. The improper management of waste is a troubling factor, as it compromises environmental hygiene and exposes the students to risks, due to the proliferation of pests and vectors in the school environment. All locations that offer feeding services should be free from vectors and pests, effecting efficient actions that impede the attraction, shelter and proliferation of them.

Environmental sanitation can be done in an adequate form using water, soap, and disinfectant for 15 minutes, drying the area immediately afterwards, or through heat disinfection (hot water) for 15 minutes. The food preparation areas should be sanitized correctly after finishing activities and always when necessary. The practice of sweeping a dry floor is prohibited to avoid the dispersal of dust.

The correct disinfection of equipments and utensils includes the use of chlorine solution for at least 15 minutes and/or the use of alcohol 70. A study in the state schools from the state of Maranhao demonstrated that the equipment and utensils are used in sub-standard cleanliness and sanitation conditions. According to Oliveira, Brazil, and Taddei, the state of conservation and the function of the equipment and utensils, as well as their condition of cleanliness, influence the final quality of a produced food.

The use of non-discardable cloths in the sanitizing and drying of the utensils, equipments and other surfaces that enter into direct contact with food is not permitted, for the cloths work as a vehicle of contamination, augmenting the risk of cross contamination. In a study by Cardoso, et al. the use of cloth towels was a practice used in all of the schools that were visited.

CONCLUSION

From the results obtained in this study, it was observed that the main problems in the school feeding production units in the children’s schools of Rio Branco – Acre are related to the inadequate physical structure and the incorrect handling of the food by the handlers involved in the production process. Another critical point that was observed was the incorrect practices relative to the personal hygiene of the food handlers and of the production environment.

So, it is important to highlight the importance of continued training about good manufacturing practices, administered
by capable professionals, the presence of nutritionists in sufficient quantities in order to supervise the process of production, and a restructuring of the physical space of the food production units, according to present legislation. These actions are necessary in order to ensure the distribution of high quality, safe and sanitary meals.

AUTHORS CONTRIBUTIONS

Alanderson Alves Ramalho designed the study. All authors collected and analyzed the data under the supervision of Alanderson Alves Ramalho. Irla Maiara Silva Medeiros and Stefany Guerreiro Lima wrote the manuscript. All other authors revised the manuscript and contributed to the discussion of the results and revision of the intellectual content. All authors approved the final version of the manuscript.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

ACKNOWLEDGEMENTS

We thank the public schools and daycares of Rio Branco for their availability and support towards the fulfillment of this research. We also thank the support from the sector of school feeding from the Rio Branco – Acre County school system.

CONSENT

The subjects (schools and food handlers) were informed about the purpose of the study and informed consent was obtained.

REFERENCES


Food Product Innovation and Food Safety: Two Vital Elements of the Global Food Security

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INTRODUCTION

Food security is one of the universally accepted and discussed current global issues of the world. Its definition informs how diverse and complicated it can be to solve this problem. It refers physical, social and economic access to sufficient, safe and nutritious food for entire population on our planet, and all the times. This sounds quite challenging task to accomplish. Food security is not merely a question of food availability, but increasingly also a question of access and even distribution of food. Globally food supply is unevenly distributed that leaves a notable proportion of the world population food insecure while others live in abundance of food. Better utilization and stability of food over time are also important aspects of food security. Now it is understandably clear that food security involves multi-disciplines (sociology, economics, political sciences, agriculture, environmental science, food science etc) as well as sub-disciplines (for example in case of food science; food nutrition, food microbiology, food biochemistry, food safety etc) to work together in order to realize the dream of global food security. Table 1 explains how different branches of food sciences could play a role.

Both food product innovation and food safety are important sub-disciplines that offer great potential to increase the productivity and the availability of foods. Innovative food products can enhance the shelf life or nutritive value or both of raw food ingredients. Food safety and quality management systems reduce the wastage due to spoilage as well as risk of microbial contamination. Several authors pointed out that efficient implementation and functioning of systems such as Hazard Analysis Critical Control Points (HACCP), Good Manufacturing Practices (GMP) and Risk Management Programmes (RMPs) in food industry were beneficial to save food items being wasted.1,2 This short article will highlight the potential role of food product innovation and food safety in future global food security.
FOOD PRODUCT INNOVATION AND FOOD SECURITY

Ensuring the availability of the foods with right nutritional benefits to the consumer is one the basic requirement of the food security. Food product innovation had played, is playing and will play a critical role to improve the bio-utilization of foods and to extend the storage period. Innovative food processing technologies are efficiently increasing the food safety and food quality. For example, High Pressure Processing (HPP) exerts a broad range of effects on different quality and safety aspects of foods and preserving the delicate nutritional elements that may lost otherwise. Another example that can be quoted here is the application of Pulsed Electric Field (PEF). PEF had shown efficient destruction of the pathogenic bacteria and maintained the good quality of soya milk. Some consumers face allergic reactions to specific foods, and there are lots of literature that suggest food processing technologies can help in reducing the food allergies. Iwan et al. reported that Maillard reaction could affect the immunoreactivity and allergenicity of the hazelnut allergen. From this example, we can see that food processing could increase the food availability towards some people who have food allergies. Lastly, food biotechnology can be useful to manage the production of animals and plants with potential benefits to have increased production for home consumption, more nutritious foods, higher gross revenues from sales, lower exposure to risks and improved natural resource management. Logically when the productivity of food ingredients is increased will influence the productivity of processing positively, hence food availability will be improved.

Food product development is another way how food innovation will play a vital role in the food security. Food product development is a process of creating novel and innovative products to benefit the customers in terms of better product shelf life and nutritional status. In this process an innovative product could be based on an existing product or an entirely new product to target a particular market segment or consumer requirement. Therefore, understanding the consumer needs and expectations will influence on the product success. Innovation in product development is not only to create new product or redevelop an existing product, but it is also an important process to increase food security. According to the world food programme website, approximately 850 million people in the world do not have enough food to consume and most of them live in developing countries. Some examples of new and innovative food products and technologies ideas that can positively impact on global food security in coming years are given in table 2.

<table>
<thead>
<tr>
<th>Food</th>
<th>Source/technology</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quorn™ Myco-protein</td>
<td>Alternative source of protein</td>
<td>8</td>
</tr>
<tr>
<td>Cultured Meat</td>
<td>In vitro meat production</td>
<td>9</td>
</tr>
<tr>
<td>Apples</td>
<td>Natural antimicrobials prolonged the shelf-life of minimally processed apples</td>
<td>10</td>
</tr>
<tr>
<td>Nuggets</td>
<td>Ganghwayakssuk extract has good antioxidant potential to improve shelf life</td>
<td>11</td>
</tr>
</tbody>
</table>

Table 2: Examples of innovative food products and technologies that can boost food supply.
which has the ability to extend the product life for unexpectedly longer periods. For example, Archeologists have found the world’s oldest cheese in China’s Taklamakan Desert and surprisingly the 3,600 years old cheese had no signs of spoilage because of the dry air and salty soil environment.14 In recent years, the number of food recalls in the US have increased partly due to a renewed focus on food safety and security by the US government. Joint efforts are being made by meat and poultry firms to prevent recalls and share new food safety technologies to ensure the quality of meat and poultry products.15 It is clear that ensuring the supply of safe food and controlling the pathogens will improve food security situation (Figure 1).

In order to maintain the food safety as a fundamental part of food security, it is required to develop systems throughout food supply chain and have improved storage and transport facilities. Implementation and effective monitoring of the food safety and quality management systems like Good Agriculture Practices (GAPS), HACCP, GMP and RMPs will be highly useful to eliminate hazards in food products. It will strengthen the global efforts to increase the food availability, thus ensuring the food safety has positive implications for food security.

CONCLUSION

Food science and technology need to pay attention towards providing solutions to the issues threatening global food security. Several disciplines within food sciences possess great potential to offer solutions in one or more ways. However, food product innovation and food safety along the food supply chain can help to improve the food security through food availability and supply. To achieve comprehensive food security it is also equally important to improve the understanding of agriculture’s vulnerability to climate change, food price dynamics, food waste and consumption patterns as well as monitoring technologies for appropriate responses to food security challenges.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

REFERENCES


12. Strange RN, Scott PR. Plant disease: a threat to global food...


Conservation of Rice Genetic Resources for Food Security

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ABSTRACT

In the Philippines, rice is a primary agricultural crop and major caloric food source of Filipinos. Rice is produced in all of this archipelagic country’s provinces, wherein total production (~18.4 million MT) is ranked eighth in the world. PhilRice was established as a dedicated research and development arm to propel sustained rice yield growth and stability toward self-sufficient production. Supporting its rice varietal improvement program is its Gene bank, a national repository of local- and foreign-sourced rice genetic materials. Currently, there are 14,388 rice accessions conserved at PhilRice Gene bank and 44% of which are landraces and traditional rice varieties. To date, 89% of the accessions have been Phenotypically characterized. To make these genetic materials desirable parent lines for rice breeding programs, a more comprehensive phenotypic characterization and evaluation of responses to various stresses remains to be done. A gene-bank’s capacity to explore genetic potential of its holdings using molecular technology advances could pinpoint important traits in potential parent lines that are valuable in developing better rice varieties. The bottom line among the challenges of rice gene banking is striking a balance between fund resource availability and undertaking the numerous core research activities, including collection, conservation, documentation, characterization, evaluation, distribution and dissemination of rice genetic materials.

KEYWORDS: Rice genetic resources; Genebank; Ex situ conservation; Landraces; Phenotypic diversity; Germplasm characterization; Rice farming practices.

INTRODUCTION

Rice is the primary agricultural crop in the Philippines. Its production of 18.4 million MT places the Philippines eighth among the world’s rice producing countries.\textsuperscript{1} Rice production is a major income source for 12 million Filipino farmers and their families\textsuperscript{2} and contributes 2.2% to the Philippines Gross Domestic Product (GDP).\textsuperscript{3} Aside from being a major caloric food source for most Filipinos, rice is a culturally important crop in the Philippines, as showcased in many traditional festivals and rituals in various parts of this archipelagic country.\textsuperscript{4,5} In 1985, the importance of rice to the Philippine economy led to the creation of the Philippine Rice Research Institute (PhilRice) enacted through Executive Order 1061. PhilRice is mandated to lead the country’s rice research and development programs that fuel the rice sector’s growth through breeding new or improved rice varieties, and developing and promoting yield-enhancing and component technologies.\textsuperscript{3}

Breeding new or improved rice varieties would benefit from readily available germplasm with excellent traits. Similar to most agricultural crops, the continuing infusion of ge-
neric resources in rice breeding results in yield stability and growth. For instance, a yield plateau was observed 28 years later from the successful release of the IR8, the first semi-dwarf rice plant type that was introduced in 1966. As such, in 1993, rice breeders proposed the development of a New Plant Type (NPT) focused on morphological traits rather than physiological characteristics, because the former were easily observable in breeding activities.

Furthermore, with current pressure to feed a burgeoning population as well as the potential effect of climate change on food production, breeding programs have recently included physiological traits that address such issues. Thus, ensuring the availability of rice germplasm with excellent morphological and physiological traits remains very crucial toward successfully breeding new rice varieties expressing desired traits.

This is one major contributory role of PhilRice’s Genetic Resources Division to any rice varietal improvement program in the Philippines. The division, among its other research activities, maintains the PhilRice Gene bank, a national repository of rice genetic materials consisting of traditional landraces, improved rice varieties, research/breeding lines, materials generated from molecular methods, interspecific hybrids, and foreign accessions among others.

In this review, focus is on the rice germplasm conservation program of PhilRice Gene bank and how these genetic resources are characterized and explored. This review also provides information about the contribution of genetic materials in rice varietal improvement, as well as limitations, prospects and the future direction of rice germplasm conservation.

CONTRIBUTION OF RICE GENETIC RESOURCES IN CROP IMPROVEMENT

Rice farmers have continually contributed to rice diversity as they cultivated selected and nurtured thousands of rice cultivars throughout time. These cultivars represent a vast wealth of genetic material, composed of landraces and traditional varieties, which are good sources of important morphological and physiological traits crucial to breeding improved rice varieties. These rice genetic resources are key components to breeding programs and serve as sources of important traits in developing better rice cultivars.

In rice breeding history, several studies have identified rice landraces as parent lines of promising new varieties. Notable of these reports are the development of IR8, and discovery of genes for submergence tolerance, and increasing rice yield. Tropical Japonica rice landrace Daringan expresses the NAL1 allele responsible for significantly increasing the yield of modern rice varieties. Rice landrace FR13A is the source of submergence tolerance SUB1 QTL. Dubbed as miracle rice, IR8 was released in 1966 and is a cross product of two landraces: Dee-geo-woo-gen, a Chinese semi-dwarf rice variety and Peta, a vigorous and tall rice from Indonesia. The rice variety IR8 is an important part of rice breeding programs in the Philippines as it serves as a parent line for breeding new varieties. One study reported that 92% of the 67 Philippine rice varieties released from 1960 to 1994 were directly related to IR8, or to IR8 through the variety Peta as a common ancestor. The study also showed that 57 common donor parents made these Philippine rice varieties related to each other. At the centre of this ancestry were 19 landraces that provided the basic template for rice varietal improvement which highlight the importance of these germplasm in the breeding program.

STATUS OF RICE GERMPLASM CONSERVATION AND UTILIZATION AT PHILRICE GENE BANK

Following PhilRice establishment in 1985, conservation of rice genetic resources through its PhilRice Genebank was initiated with an initial collection of around 300 varieties reacquired from the International Rice Research Institute (IRRI). The germplasm holdings increased through donations and various explorations conducted around the country. A collaborative project between PhilRice, IRRI and the Swiss Agency for Development and Cooperation conducted in the mid-1990’s to safeguard rice genetic resources in the country resulted in the acquisition of 458 traditional rice varieties. To improve the management and operation of the Genebank, an operation manual was published serving as a protocol to the daily activities of the Genebank.

To date, the PhilRice Genebank is conserving 14,388 rice germplasm both from local and foreign sources (Figure 1). Nearly half of the collections (44%) are traditional rice varieties, while the second largest portion of the collection (32%) represents breeding lines and improved varieties donated by various researchers and breeders.

To fill in the gaps in the collection with emphasis on provinces in the country with limited representation in the germplasm collections, a PhilRice-funded project to conduct and ecogeographic survey and collection was implemented in 2008. A total of 387 samples were collected during the conduct of the project. Assessment of the collections phenotypic diversity showed high diversity in the agronomic traits measured. Table 1 provides a glimpse of the phenotypic diversity in selected grain traits of the 387 rice germplasm collection. Awn length is the only grain trait that showed low diversity because most of the collected germplasm had no awns. Presence of awns is one of the peculiar traits in the Indonesian bulu or javanica group within the tropical japonica varieties. Analysis of correlation among the agronomic traits showed several traits to be highly correlated. The size of the flag leaf width was shown to be highly correlated with some grain traits, such as grain and caryopsis width. Flag leaves are important in grain filling stage in rice as it contributes to 80% of the total carbohydrates as well as being a source of photo assimilates during water stress.
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Figure 2 illustrates the germplasm diversity (A) and (B) some of the indigenous rice farming practices (B) that were observed during the collection mission. These practices could form part of the documentation process of germplasm acquisition. The most interesting farming practice noted was the use of coconut palm stalks in paddy fields, resembling snakes ready to strike, and therefore acting as decoys to scare away rats. This practice is common to provinces of the southern Luzon region of the country.

Germplasm characterization and evaluation are two important components of an efficient utilization of germplasm materials. Germplasm evaluation is more useful if the traits measured are of interest to breeders. Phenotypic characterization based on selected traits from the internationally agreed upon standards has been carried out on much of the germplasm conserved at PhilRice Genebank. To date, 89% of the accessions conserved are fully characterized (Figure 1). What is lagging is the comprehensive phenotypic evaluation of the whole collection based on important traits that breeders need to breed for improved varieties. Also, evaluation of germplasm based on their response to various stresses has commenced, but so far only 12% and 3% of the total accessions conserved underwent evaluation for biotic and abiotic stress, respectively. For grain quality evaluation, 34% of the collection has been screened. Phenotypic characterization at PhilRice Genebank is usually carried out alongside regeneration of germplasm, which explains why most of the collections had been characterized. Germplasm evaluation on the other hand requires technical inputs from end users who have variable traits of interest, so this activity was carried out in collaboration with breeders and researchers at the Institute.

CHALLENGES AND FUTURE DIRECTIONS IN RICE GENETIC RESOURCES CONSERVATION

One of the challenges in a genetic resource conservation program is access to actual field materials. Some areas remain remote because of poor road networks. Researchers need to walk or hike many kilometres during exploration trips to collect germplasm. An example is the collection trip to Aurora, one of the Philippine provinces that is highly engaged in rice production. Researchers had difficulty in reaching farming areas because of poor farm-to-market roads. Figure 3 shows the location of the rice varieties collected in Aurora province. Notice that the...
samples collected were close to road networks, while not much collection was done in areas that lacked road infrastructure.

Collection bias due to infrastructure is common in collection missions because collectors tend to follow roads that connect to main towns for the reason of efficiency, logistics and convenience.22 This bias has been observed in numerous germplasm collections.22-24 Hermann23 reported that most of the Andean tuber crop collection sites sampled in Ecuador were located near the Pan-American Highway and other major roads. The same observation was noted by Von Bothmer and wherein the distribution map they constructed showed that most of the collection sites for *Elymus cordilleranus* were located around major cities like La Paz (Bolivia), Lima (Peru) as well as the Pan-American Highway in Ecuador. The same observation can be noted for the Bolivian collection of wild potatoes, wherein 68% of the total germplasm holdings were collected within 2 km of the nearest roads.25 Geographic distribution of *Huperzia* also revealed that most of the collection sites were located near roadways.25 To gain access to areas that are far from the main road networks, collaboration with local government and non-government organization (GO and NGO) personnel could facilitate effective and efficient collection missions.

Another challenge in germplasm conservation is managing the increasing amount of material. *Ex situ* conservation is expensive, and maintenance of these materials for a long period of time will require sustained funding. A cost analysis done on major gene banks around the world showed that the annual cost could range from US $0.6 million to US $1.2 million, depending on the location and total germplasm holdings.26

In rice genetic conservation, IRRI holds the largest collection of rice germplasm, with 126,601 accessions conserved. IRRI requires an annual budget of US $797,553 to conserve and disseminate its germplasm,26 of which 61% of the total cost is allocated for labour. Since gene banks do not have unlimited resources at their disposal, gene banks should consider the size and scope of their collections, while conserving as much of the total crop gene pool as possible.27 To rationalize the number of

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**Figure 2A:** Diversity of rice germplasm collections. 2B: Some Filipino farmers’ practices in rice production: panicle drying (top), and use of coconut palm as rat deterrent (bottom).

**Figure 3:** Location map of Philippine traditional rice varieties collected in Aurora province.
Accessions for conservation, prioritization in material acquisition must be practiced. Another option is to reduce redundancy in the collection by developing a core collection that would represent the genetic spectrum of the entire conserved genebank collection. This approach was taken by Ebana, et al. for Japanese rice landrace, where a core collection composed of 50 accessions was developed, based on an original collection of 236 accessions. They were still able to retain 87.5% of the alleles that had been detected in the original collection.

Another challenge to rice gene banking is the availability of phenotypic evaluation data of germplasm collections for potential traits that can be utilized in breeding programs. One of the major reasons why germplasm may be under-utilized is a lack of evaluation data that breeders can use for their parental choices. This is a common challenge in most gene banks around the world, and it has become a major priority activity for the Global Plan of Action on the Conservation and Sustainable Use of Plant Genetic Resources for Food and Agriculture. Unlike characterization that can be carried out during the regeneration of germplasm, phenotypic evaluation requires more technical expertise, financial inputs and specialized facilities, and some gene banks do not have the ability to implement this activity. One approach to address the issue of insufficient evaluation data in the germplasm collection is to share the responsibilities with researchers and other germplasm users. At PhilRice, we have collaborated with researchers from various fields (plant breeding, entomology, plant pathology and chemistry) to generate phenotypic evaluation data that can be useful for breeders and other stakeholders.

In the future, the availability of genotypic and phenotypic data from the rice germplasm conserved in gene banks could facilitate rice breeders to efficiently and rapidly incorporate important traits in the development of new high-yielding varieties with enhanced tolerance to biotic and abiotic stresses. This assumption is based on the premise that the continuing infusion of genetic resources in rice breeding programs will result in yield stability and growth, as previous breeding breakthroughs have demonstrated.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

CONSENT

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REFERENCES


29. FAO (Food and Agriculture Organization). The second report on the state of the world’s plant genetic resources for food and agriculture. FAO, Rome, Italy. 2010
