Seasonality Revisited

Perspectives on Seasonal Poverty

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Richard Strange

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Richard Strange

Editor-in-Chief "Food Security"
School of Biological and Chemical Sciences,
Birkbeck College,
University of London,
Malet Street,
London WC1E 7HX,
UK

Abstract

Most crop plants are seasonal, giving rise to alternating periods of glut and dearth. Three ways of avoiding food deprivation in the periods between harvests are to grow crops that are non-seasonal, to diversify diets, so that for every month of the year some edible plant is available and to store the produce.

Cassava is non-seasonal and can be harvested as early as 6 months and as late as 24 months after planting, providing the tuber remains attached to the aerial parts of the plant. Not surprisingly, this staple of the African Continent is known as a 'famine reserve crop'.

In the Amhara region of Ethiopia there are 48 wild fruit species, which are rich in valuable nutrients. At least four of these are available at any one time, including times of acute food and nutrient scarcity. Unfortunately, little use is made of them owing to local customs and taboos (Fentahun and Hager, 2009).

On the African continent, almost 30% of all crops are lost during storage and this rises to about 50% for fruit and vegetables (FAO 1989; Reusse 2002). Part of this loss is caused by foraging animals and insects, theft and deterioration but often the main enemies are microorganisms. Besides causing deterioration, they may elaborate toxins, some of which cause a variety of symptoms including cancer and death.

Methods for preserving food stuffs are canning, refrigeration, addition of antimicrobial chemicals, salting, smoking and drying. The last of these is the most appropriate for hot climates but difficulties arise where humidity is high.

Produce, when first harvested, almost invariably has a high water content but drying is difficult as it involves the simultaneous evaporation of water and the need to remove it. Direct exposure to sunlight, even in the tropics is inefficient and leads to contamination by microorganisms and non-biological material. A prototype of a solar dryer has been built in Mali with local materials and has been used to dry 40 Kg of tomatoes per day. The product could be stored for a year, clearly an advantage in a country where the harvest period for this crop is only 3 months (Nonclercq *et al.* 2009).

Introduction

At present around 1 billion people are not food secure – the bottom billion (Collier, 2007). That is, they do not have, at all times, physical and economic access to sufficient safe and nutritious food to meet their dietary needs and food preferences for a healthy and active life (FAO 1996). These are the people who live in the developing world where life expectancy is around 45 years whereas in the developed world it is around 75. To what extent can the short life expectancy of the bottom billion be laid at the door of seasonality? Clearly, the fact that most staple foods are seasonal must be a contributing factor. Gluts at harvest are succeeded by dearth at other times. One way in which this difficulty can be overcome is by growing non-seasonal crops which can be harvested at any time of the year. Another is to grow crops that mature at different times so that there is a ready source of food throughout the year. Inevitably, storage must enter the equation but this exposes food stuffs to multiple hazards. One of the most insidious of these is the production of mycotoxins.

Non-seasonal crops

Taking the world as a whole, wheat, rice and maize provide 60% of the energy intake. All three are seasonal. For Africa, where hunger is often acute, cereals form around 46% of the diet and roots and tubers 20%. Among the latter, cassava (*Manihot esculenta*) is predominant. It is non-seasonal and can be harvested as early as 6 months and as late as 24 months after planting, providing the tuber remains attached to the aerial parts of the plant. More than 80% of cassava produced in the world is consumed by human beings and it is the principal carbohydrate source for more than 500 million people in the tropical world (Lozano, 1986; Fauquet and Fargette, 1990). Nweke *et al.* (1999) reported in their working paper on the Collaborative Study of Cassava in Africa (COSCA) that cassava is the most important of all the arable crops cultivated in Ghana. The COSCA report further revealed that villages in Ghana that did not experience famine in 1983 were those which cultivated cassava as the dominant staple crop. In contrast, areas where other major staples such as plantain, maize, millet and sorghum were considered to be more important, experienced severe famine. Moses (2009) reported that famine rarely occurs in areas where cassava is grown widely because of its relative reliability compared to other crops.

Unfortunately, there are problems with cassava. In the first instance it contains highly toxic cyanogenic compounds, mostly as the glucoside, linamarin. Consequently, it has to be carefully processed in order to reduce their concentration. The most effective method is pounding or crushing as this breaks down the compartmentalisation of linamarin and the enzyme linamarinase, allowing the enzyme to catalyse the hydrolysis of the compound to glucose and acetone cyanohydrin. The latter compound breaks down spontaneously to acetone and hydrogen cyanide, which is volatile. Disease is another problem, particularly that caused by African Cassava Mosaic Virus (ACMV). Unfortunately, in the late 1980s an unusually severe form of the disease appeared in Uganda and has since spread. It results from double infection, the two viruses being a recombinant virus derived from ACMV and a variant of East African Cassava Mosaic Virus (EACMV) termed UgV. The reason for the severity of symptoms is that each suppresses the plant's mechanism for dealing with infection of the other (Vanitharani *et al.* 2004).

Seasonality not only affects what can be grown and when, it also affects the prevalence of plant diseases which can spell ruin and starvation. Chickpea is an important crop in many areas of the world such as West and Central Asia, North Africa, Australia and North America. In Pakistan chickpea, owing to its high protein content, is known as "the poor man's meat". However, blight caused by the fungus, *Ascochyta rabiei*, destroyed around 50% of the chickpea crop in Pakistan in the 1980s and continues to be the major biotic constraint limiting chickpea production almost everywhere it is grown, apart from India where the weather is usually too hot (Nene et al., 1982).

Severe attacks may result in total loss of the crop (Reddy and Singh, 1990; Singh et al. 1981; Singh and Reddy, 1990; Solh et al. 1994) and, in some years, the disease has even affected international trade (Dusunceli et al. 2007b). Spread of the disease is favoured by cool and wet weather such as occurs in winter in the Mediterranean region. In Turkey, some farmers sow chickpea as late as early March or even April, in order to avoid the disease, but Dusunceli *et al.* (2007a) found that yields from such late plantings were limited by the onset of hot and dry weather before maturity. In an experiment on planting dates in Tunisia, chickpea sown between December and February suffered severe disease and gave poor yields but those sown in March escaped the disease and gave good yields (Ben Mohamed et al. submitted for publication). These experiments show that planting date must be carefully gauged in order to avoid the Scylla of Ascochyta blight and the Charybdis of scorching.

Diversifying the cultivation of food crops

Historically, humans are thought to have consumed over 3,000 plant species but now fourteen crop plants provide the bulk of food for human consumption (Strange and Scott, 2005). Moreover, the genetic pool of these is limited. A recently published book with the pertinent title "Genetic Glass Ceilings" emphasises this limited genetic pool and makes a strong case for obtaining genes from other sources – i.e. genetic modification (Gressel, 2008).

Dealing with the current situation one may ask, in the first instance, if full use is being made of plants that are readily available in areas of deprivation. There is considerable evidence that the answer is no. For example, 90% of the people living in about 40% of the land area of Bangladesh are hunger prone and suffer severe seasonal hardship in the months of September to November and April to May. Here it is possible to grow indigenous vegetables such as *Moringa*, sword bean (*Lablab* spp.), country bean (*Dolichos* spp.), *Luffa*, aroids (*Colocasia, Amorphophallus, Alocasia, Xanthosoma*), cucurbits, yam (*Dioscorea*) and leafy vegetables and that doing so supplements food, nutrition and income by 20, 50 and 40%, respectively. However, by adjusting existing cropping patterns and homestead planting it is possible to grow more (Rahim *et al.* 2007). In another paper, Jana (2007) draws attention to the fact that in the terai region of West Bengal the promotion of only a small number of vegetable crops had systematically replaced many indigenous crops which were traditionally planted and consumed by local subsistence farmers or gathered from the wild. They include kochu (*Colocasia esculenta*), punarnaba (*Boerhaavia* *diffusa*), thankuni (*Centella asiatica*), bathua (*Chenopodium album*), Kalmi (*Ipomoea reptans, I. aquatica*), helencha (*Enhydra fluctuans*), dhekii sag (*Diplazium frondosum*), telakucha (*Coccinia grandis, C indica*), gandhabhadali (*Paederia foetida*), kharkol (*Arum* sp.), kulekhara (*Asteracantha longifolia*), dhundhul (*Luffa cylindrica*), brahmii (*Bacopa monnieri*), safla (*Nymphaea dauberyana*) and shusni (*Marsilea quadrifolia*). They are highly recommended owing to their relatively good nutritional value, their importance for food security and for income generation. These plants therefore appear to be a promising resource and worthy of research which could, perhaps, lead to resumption of their use and further exploitation by domestication.

In Mexico the cebollín (*Allium longifolium*) was an important food source in the past and the techniques for gathering it are thought to have increased its prevalence but currently it is now little used (Bye 1993). Perversely, in some areas that are chronically food insecure, the gathering of nutritious wild species of plants is frowned upon. For example, in Ethiopia there are strong traditions, beliefs and religious taboos which inhibit people's psychological and mental willingness to use wild plants (Guinand and Dechassa, 2000). Recently, Fentahun and Hager (2009) described 48 plant species growing wild in the Amhara region of the country which produced fruit of nutritional value although 15 of these had one or more unpleasant characteristics such as a sharp taste or causing constipation. However, gathering such fruit was considered to be indicative of famine and its consumption undignified, attracting social stigma. Moreover, in a survey, 3% of the informants stated that they would be ashamed to domesticate wild fruits, 20% had never thought about the possibility and, ironically, 29% were constrained *because* the fruit were freely available. This seems particularly contrary in a region which is stalked by famine but where, in any month of the year, there are fruit available from at least four species. Also, in this part of Ethiopia, Enset, a wild banana (*Ensete ventricosum*), is not considered as food whereas in the southern part of the country it is a staple for millions (Pijls *et al.* 1995; Fentahun and Hager, 2009).

Recently, the cultivation of *Arisaema schimperianum*, known locally as amochi, as an off-season crop has been reported from Southern Ethiopia, although uncooked it is an irritant of the skin, including the mouth. Fifteen types of the plant were identified which differed in levels of irritant and yield. Consumption of the tubers varied as a proportion of total annual household consumption from 4% - 9% (Gedebo *et al* 2007).

Processing and Storage

On the African continent, almost 30% of all crops are lost during storage and this rises to about 50% for fruit and vegetables (FAO 1989; Reusse 2002). The harvestable parts of many plants are not easily stored, owing to their high water content. However, there are some exceptions. The vast majority of yam is grown on the African continent, around 40 million tons per annum, most of it in Nigeria. Fortunately, yams can be stored for up to 6 months without refrigeration. However, a study of yams from a yam barn and selected markets in Accra, Ghana revealed the presence of rots caused by nine spoilage fungi, which included *Aspergillus flavus* (Aboagye-Nuamah *et al.* 2005). Both yam and cassava can be processed to give chips but a recent study in Benin gave some disturbing results (Gnonlonfin *et al.* 2008). First, the moisture content was too high to prevent the growth of fungi - 10.0 to 14.7% in cassava chips and 11.4 to 15.3% in yam chips and secondly a number of spoilage fungi were found, including *A. flavus* although, surprisingly, no aflatoxin (see later).

In Southern Ethiopia, Enset or false banana (*E. ventricosum*), is an important source of food, as mentioned above, yielding as much as 9.5 tons ha^{-1} $year^{-1}$. When harvested the pseudo stem is scraped in order to separate the starchy pulp from the fibre and the corm pulverised. The resulting pulp is fermented and the product (ko'cho) may be stored for up to 7 years in earthen pits (Pijls *et al.* 1995).

Although cassava is a year round crop it may be processed to give a variety of products such as gari and fufu. In all cases it is important that the sources of cyanide are removed (see above). For gari, a flour made from cassava tubers, the tubers are peeled and the white pulp is grated either by hand or machine. The grated product is fermented in jute sacks for 3 – 7 days, a crucial part of the process as this reduces the cyanide content. Water is removed from the product by pressure and the flour is obtained by sieving in order to remove large particles. In Ghana, fufu is the national dish and it is made by beating together cassava and plantain.

In Mali, tomato is a common consumer product and is sometimes used daily. Owing to a favourable climate and the recent employment of irrigation techniques, local farmers have been successful in cultivating the crop. However, harvesting is limited to three months of the year - January to March. As a result there is a surplus during these months leading to a significant drop in prices while during the rest of the year tomatoes are usually imported from Italy or Morocco as canned purée. As Nonclerq *et al.* (2009) state, “It is an economic paradox that a country able to cultivate tomatoes imports them as a processed product from countries that are richer and distant”. Nonclerq *et al.* (2009 also detail the unhygienic methods that retailers use to sell tomato purée, such as leaving cans open for a number of days and transporting the purée on re-used paper from a journal or fertiliser bag!

In order to overcome these problems Nonclerq *et al.* (2009) designed a drier which could be constructed from materials readily obtained in Mali. The unit overcomes the difficulty of the simultaneous evaporation of water and the need to remove it by using solar heaters to warm water to 65^{o}C which is circulated to a tank. The warm water from the tank is further circulated to radiators in a tower. Material to be dried is placed on the radiators and air passed through the tower to remove the evaporated moisture from the product. The unit was capable of drying 40 Kg of tomatoes per day under Malian conditions, assuming a daily quota of ten hours’ sunshine. Other fruits and vegetables could also be dried. Tomatoes dried in the unit could be kept at room temperature for more than a year without deterioration.

Mycotoxins

Apart from foraging animals and insects, theft and physical deterioration, microorganisms can wreak havoc in stored produce. In particular, there are considerable dangers from mycotoxins. These are toxic compounds produced by fungi in food crops during the growing season, in storage or both. Two outstanding examples are the fumonisins and aflatoxins. Both exist as a family of compounds but in both cases the ones designated B1 (fumonisin B1 and aflatoxin B1) are the most hazardous.

The fumonisins were discovered as a result of an investigation into the high incidence of oesophageal cancer in the Transkei region of South Africa (Sydenham *et al.* 1990). One hypothesis for the relatively recent increase in cancer in this region is the change of the staple diet of Black South Africans from sorghum to maize beginning in the early part of the twentieth century. Several species of *Fusarium* can infect maize but sorghum is more resistant (Isaacson, 2005). The fumonisins are frequently found in maize infected with species of *Fusarium,* in particular *F. verticillioides* and *F. proliferatum*. For example, fumonisins were detected in 100% of maize samples from Paraná State in Brazil in 2003 and over 98% in 2004. Mean concentrations were 2.54 and 1.31 $\mu g.g^{-1}$, respectively (Moreno *et al.* 2009). Similarly, fumonisin B-1 (FB1) was found in all of 282 samples of maize harvested in 2005 in six provinces of China. Concentrations varied from 3 to 71,121 $ng.g^{-1}$ with mean and median levels for all samples of 6,662 and 1,569 ng/g, respectively. Samples could be divided into those where the concentration was less than 1,000 $ng.g^{-1}$ (43.6%) and those with more than 5,000 $ng.g^{-1}$ (25.2%). According to an extensive study in the Argentine and the Philippines, about half of the variation in fumonisin concentration in maize grain was explained by weather or location (de la Campa *et al.* 2005). Experiments in Italy have shown that there is a seasonal effect. Late sowing, after May 10, multiplies the risk of the occurrence of fumonisins in grain at harvest by a factor of 11.2 (Blandino *et al.* 2009a). In a later paper these workers showed that fumonisin contamination was reduced by 86% when early sowing in March was combined with low plant density, fertilizer application and control of European Corn Borer (ECB), which acts as a vector for *F. verticilloides,* compared with late planting, high plant density and no control of ECB (Blandino *et al.* 2009b).

Aflatoxins produced by *Aspergillus flavus* and *A. parasticus* were first identified in contaminated peanut meal (Lancaster *et al*. 1961). They cause acute hepatitis and liver cancer in animals. In humans they also cause acute hepatitis and have been associated with liver cancer, particularly in sub-Saharan Africa and southeast Asia (Groopman *et al.* 1996). Liver cancer is the cause of more than 200,000 deaths annually in China (Wang *et al.* 1999). They have been held responsible for deaths by acute poisoning of 317 people in Kenya in 2004 of whom 125 died. Evidence that this outbreak resulted from aflatoxin poisoning included high levels of aflatoxin (up to 8,000 ppb) in maize samples collected from patient households, clinical illness consistent with acute aflatoxin poisoning, clustering of cases among residents of the same household and reports of deaths among animals known to have eaten the same maize as the patients during the same period (CDC, 2004). The largest reported outbreak of aflatoxicosis to date occurred in western India in 1974, resulting in 397 recognized cases and 106 deaths. Unlike the fumonisins for which production ceases upon harvest (Gressel, 2008) aflatoxins go on being produced in storage. Perhaps their most insidious effects result from lower doses. These impair liver function and lower the efficiency of food conversion (Gong *et al.* 2002). Moreover, the seasonal occurrence of Kwashiorkor syndrome in young children coincides with the seasonal occurrence of aflatoxins in the diet (Hendrickse, 1999). In this context it is perhaps pertinent to mention that drought stress predisposes peanuts to infection by *A. flavus* and *A. parasiticus* . Over 20 years ago a former Ph.D. student of mine, Hilary Wotton, associated this increased susceptibility with an impaired defence response of the plant (Wotton and Strange, 1987).

Conclusion

Most crops are seasonal owing to their physiology and to the climate in which they are grown. In regions of the world where preservation and storage techniques are well developed this does not present a great problem. However, in the developing world, where such techniques are not available there is likely to be an alternating occurrence of glut and dearth. In these circumstances it is important to develop the means by which shortages are avoided. Diversifying the crops that are cultivated for consumption is one means but this has to be done with care and due attention to the physical conditions of the environment and the social conditions of the people. Gathering food materials that can be found growing wild is one measure to alleviate the food gap in hunger months. Domesticating such plants may provide a longer term solution as has been done with the cactus *Polaskia chichipe* in Mexico (Carmona and Casas, 2005). Reducing the moisture level of food stuffs below that at which they can be invaded by microorganisms is essential if they are to be stored and the method of storage itself must be dry and sufficiently secure to prevent invasion by foraging animals and insects.

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