Nutrition Science ⇄ Policy

Underexploited African Grain Crops: A Nutritional Resource

Jed W. Fahey, M.S.

The African grain deficit is projected to surpass its current production of 50 × 10⁶ metric tons/year by the turn of the century. The biodiversity of the African continent, on which there are more native cereals than on any other continent, can serve to reduce the vulnerability of that continent's populations at serious risk of food shortages. Traditional grain and root crops have provided the energy underpinning for Africa since the emergence of bipedal hominids. By resurrecting some of these "lost crops" in their native areas, the food security of those areas can be enhanced. In addition, some of these crops lend themselves to introduction into other nutritionally challenged areas of the world with similar geoclimatic characteristics.

African Cereal Crops

Acreage of the world's current "premier" grain crops, such as rice imported from Asia about 1000 years ago, maize imported from Central America about 500 years ago, and wheat imported from the Levant in recent decades (Table 1[1]), has been increasing steadily. These increases have invaded the acreage devoted to the better-adapted and more serviceable (e.g., nutritious) native grains that have supported local populations since the emergence of anatomically modern humans. This inexorable expansion of the world's premier crops has fostered increasing monoculture of both inedible fiber sources and edible crops, especially the cereals. To the extent that it has affected portions of Africa without concomitant major changes in food production technologies, this expansion, Harriss[2] suggests, is actually accompanied by "a reduction in traditional practices ensuring food security at the household level, increases in the female work burdens, and higher incidences of malnutrition and morbidity than in neighboring less commercialized regions." Furthermore, according to Harriss,[2] one of the impacts of research on food grains (major crops such as wheat, rice, and maize) in developing countries may actually be increased rural and urban malnutrition, even in the presence of increased gross national product (GNP) and improved food security on a national level.

Other researchers have been even less munificent in their assessment of events leading up to the present reduction in African grain diversity. Onorati and Gaifaini[3] blame the Green Revolution for "the destruction of traditional local knowledge, techniques and habits, [which] caused disruption of the very sophisticated biologic links cementing the natural environment to those traditional agricultural techniques which constituted the basis of any sustainability."

Although imaginative strategies are being employed to enhance, for example, the mineral content of introduced staple crops,[4] increasing yields of these staple crops will likely not be sufficient to improve nutriture. In fact, diversification and a trend away from monoculture may be more critical in the African continent than any place else in the developing world. Aside from genetic diversification, various alternative agricultural systems, such as intercropping, are being explored in eastern and southern Africa; these achieve maximal use of arable land by comingling an understory of food crops with hedgerows, palms, or juvenile forest plantings.[5,6] The genetic "rediversification" of African cereal crops, however, holds the greatest potential to limit the threat borne by excessive proliferation of imported crop monoculture.

Three of the world's top eight grain crops are of African origin, but these three crops receive only a small fraction of the research attention that the other five receive (Table 2). Research, primarily in industrialized nations, has dramatically and steadily increased the productivity of maize, wheat, and, to a lesser extent, rice. Through a combination of germplasm development, energy-intensive farming practices, and aggressive pesticide application, these premier crops have replaced native crops in many areas of the world where those native crops are, in fact, far better adapted. A combination of government policies, enhanced yield brought about by intensive research, and ease of processing maize and wheat has contributed to their preeminence among the grains. As climatic conditions predispose maize, wheat, and rice crops to fail repeatedly

Mr. Fahey is a Faculty Research Associate in the Department of Pharmacology and Molecular Sciences, School of Medicine, Johns Hopkins University, Baltimore, MD 21205-2185, USA.

Table 1. Chronology of Cereal Domestication[1]

100,000 B.C.	Wild grains eaten in Africa.
75,000 B.C.	Neanderthal man develops as skilled hunter.
38,000 B.C.	*Homo sapiens* emerges, develops control of fire.
12,000 B.C.	Halfan tribespeople on Egypt's lower Nile use grinding stones to produce a flour from the seeds of wild cereal grasses. Flint-bladed reaping knives employed to harvest wild cereals that have started to flourish since the end of the Ice Age.
11,000 B.C.	Vast fields of wild grain appear in parts of the Near East as the glaciers retreat.
10,000 B.C.	Mammoths disappear; goats are domesticated.
9000 B.C.	"Golden age"of nutrition. Humans' cardiovascular system, taste buds, and food supply in harmony: game, vegetables, fruits, nuts, berries, fish, shellfish, no dairy products, no grain, 20% of calories from fats, no heart disease.
8000 B.C.	Perennial sources of wild grains; final postglacial climatic improvements; agriculture begins with cultivation of seeds of wild grasses.
7000 B.C.	Emmer wheat (*Triticum dicoccum*) domesticated in Kurdistan (Turkey-Iran). Barley (*Hordeum spolitalieum*), millet (*Panicum miliaceum*), and legumes, including lentils cultivated in Greece. Chinese domesticate foxtail millet (*Setaria italica*) and panic millet.
5000 B.C.	Chinese cultivate rice (*Oryza sativa*) that originally appeared as a weed in flooded patches used to grow taro root (*Colocasia esculenta*) that may have been the first crop ever cultivated.
4000 B.C.	First indication of insect and rodent infestation due to large fields of grain in Indus Valley with wheat, barley, peas, sesame seeds, mangoes, and date palms on irrigated fields.
1680 B.C.	Leavened bread is invented in Egypt. Bread for the rich is made from wheat flour. Bread for the less affluent is made from barley. Bread for the poor is made from sorghum.
27 B.C.	Roman diet chiefly a gruel called puls, made from barley, millet, wheat, or oats.
16 A.D.	Rome imports 14 million bushels of grain/year to supply city: one-third from Egypt and the balance from other North African territories.
1000 A.D.	Arab traders bring Asian rice to Africa.
1550 A.D.	Portuguese colonists bring American maize to Africa.
1950 A.D.	Wheat introduced to Africa from temperate zone.

Information from Trager (1995).[1]

owing to their lack of adequate adaptation to environmental pressures, the fitness benefits of native crops is becoming apparent. Under extreme conditions, the farmers' desire for enhanced profit becomes subservient to the desire to survive and to produce a crop—even if at a comparatively low yield.

Seventy or so native African grasses—more than from any other continent—hold potential for increased development and utilization owing to their hardiness and their tolerance to disease, water stress, and competition from native weeds. Some of these African cereal crops are highlighted in the National Research Council's recent report *Lost Crops of Africa*.[7] The utilization of at least some of them may well be vital for extending cereal production onto lands that are becoming ever more marginal because of increasing desertification and nutrient depletion.

Importance of Native Cereals in the Development of Weaning Foods

One of the greatest potential benefits of promoting or reintroducing native grains is in their use as weaning foods. The practices of malting and lactic acid fermentation have been commonplace in many cultures to reduce food bulk and to aid in the development of suitable weaning foods. The process of germination or sprouting enhances the flavor, palatability, and digestibility of grains through action of the enzyme α-amylase, which is released during the sprouting process. Release of this and other hydrolytic enzymes peaks at only 2–3 days of age for finger millet and pearl millet and 4–5 days for numerous other grains.[8] As a result of this process, starches are broken down into more readily digestible sugars, thus liquefying, sweetening, and enhancing the nutritional value of food products made with these millets.

In many cases, infants cannot consume an adequate amount of calories, protein, and other nutrients when fed high-bulk gruels or porridges. Despite the availability of adequate food within the household, these infants, when weaned from breast milk, may fill their stomachs with a high-bulk, low-energy porridge, yet still not ingest sufficient calories to thrive. By liquefying thick cereal porridges to produce energy-dense weaning foods, malting can make significant progress toward ameliorating the malnutrition that is so frequently associated with transitional feeding.

The millets are exceedingly rich in α-amylase activity, and when sprouted, redried, and ground to a flour (malting), a small portion of malted millet flour can subsequently

Table 2. Research Attention Accorded to Selected Grain Crops[a]

Crop	Genus and Species	Area of Origin	*BA*[b] Citations
Wheat	*Triticum aestivum*	Middle East	22,693
Rice	*Oryza sativa*	Asia	13,782
Maize	*Zea mays*	Central America	20,313
Barley	*Hordeum vulgare*	Middle East	8535
Sorghum	*Sorghum bicolor*	Africa	3833
Pearl millet	*Pennisetum glaucum*	Africa	886
Rye	*Secale cereale*	Middle East	2513
Finger millet	*Eleusine coracana*	Africa	214
African rice	*Oryza glaberrima*	Africa	59
Bourgou	*Echinochloa stagnina*	Africa	5
Crowfoot grasses	*Dactyloctenium* sp.	Africa	23
Drinn	*Aristida pungens*	Africa	2
Emmer	*Triticum dicoccum*	Africa	164
Ethiopian barley	*Hordeum vulgare*	Africa	7
Ethiopian oats	*Avena abyssinica*	Africa	5
Fonio	*Digitaria exilis, D. iburua*	Africa	82
Guinea millet	*Brachiaria deflexa*	Africa	4
Kodo millet	*Paspalum scrobiculatum*	Africa	29
Kram-kram	*Cenchrus biflorus*	Africa	6
Panic grasses	*Panicum* spp.	Africa	2
Tef	*Eragrostis tef*	Africa	191

[a]The top eight grain crops worldwide, followed by a selection, in alphabetical order, of native African grains gleaned from a recent, comprehensive National Research Council report.[7] These crops are followed by the number of citations obtained in a 7-year retrospective search of *Biological Abstracts* (1989–1995). Although only a crude index, this citation count provides an indication of how little research attention the native African crops have received.
[b]*Biological Abstracts.*

be added to millet or other grain porridges to achieve the sweet liquid outcome of enzymatic starch hydrolysis. These porridges naturally assume a pasty, gel-like consistency owing to the hydrated starch and other soluble fiber that they contain. When mixed with malted flour, however, they rapidly liquefy, and in addition to hydrolyzing starches (α-amylase), other malt enzymes hydrolyze certain proteins and even some of the flatus-inducing factors. The porridges, therefore, become more easily digestible and more nutrient-dense, with better vitamin availability, sweetness, and flavor. The palatability, protein quality, and bioavailability of finger millet malt have been demonstrated to be superior to those of many other grains (e.g., pearl millet and rice).[8–11]

Recent work from Tanzania has examined the energy density of *togwa*, the traditional sweet gruel made from malted cereal grains. In a comparison of togwa prepared from maize, bulrush millet, sorghum, and finger millet, the sweetest and least viscous togwa with the most desirable sensory analysis was produced from finger millet.[12] Finger millet seeds (major components of birdseed in the United States) have the additional advantage of resisting mold and deterioration during germination, are particularly high in protein, methionine, and calcium, and are free of goitrogenic cyanogenic glycosides.[7] Additionally, the roots of these plants harbor associative dinitrogen-fixing bacteria,[13] thus offsetting the plant's requirements for exogenous nitrogen and significantly reducing the need for fertilizer.

Fermentation is commonly associated with the production of alcoholic beverages by yeast (e.g., *Saccharomyces* spp.) via the conversion of sugar to ethanol plus carbon dioxide. Alternatively, sugar can be converted to lactic acid, typically via *Lactobacillus* spp. Cereals fermented with lactic acid (e.g., *ogi*, a Nigerian gruel made from a fermented slurry of sorghum, millet, or maize) have long been known to be of thinner consistency than the unfermented porridge made from the same grains; this is attributed to the reduced pH of the fermented product. These foods have enhanced energy density (like the malted products, but not as dramatic), making them suitable as weaning foods.[14] Additional advantages of using a lactic acid–fermented cereal porridge as a weaning food include enhanced levels and bioavailability of proteins, vitamins, and minerals, and flavor enhancement and enrichment through synthesis (bacterial) of B vitamins.[7] Other advantages that have been ascribed to such fermented cereal products have been extensively reviewed by Dirar,[15] who stresses that the invention, preservation, and consumption of these fermented foods have, since antiquity, been strongly linked to survival.

Lactic acid–fermented weaning foods also appear to have a significant effect on the frequency of diarrhea.[16] The fermented porridge *matoho* reduced the titer of enteropathogens such as *Salmonella typhimurium, Shigella* spp., *Escherichia coli*, and *Campylobacter jejuni* in vitro in a Tanzanian study.[17] Recent work by Yartey et al.[18] suggests that an aqueous dilution of *kenkey*, a fermented maize gruel widely used in Ghana, might be used as an oral rehydration solution (ORS). It was suggested that kenkey water would be more available and more culturally acceptable than the ORS used by the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF), since it contains similar levels of electrolytes and carbohydrates.[18,19] Populations of test pathogenic bacteria in kenkey were reduced by one to three logs in 30 minutes.[20] The reduced transmission of enteric pathogens—thought to be a direct result of lactic acid production—has attracted considerable research interest as a secondary benefit of fermented weaning foods.[21] Because diarrhea that occurs during the transitional feeding period is a major cause of dehydration and can lead to malnutrition and ultimately starvation in this extremely high-risk population, the antidiarrheal effect of such fermented cereal gruels could translate into significant public health benefit.

Conclusion

A compelling argument can be made that many of the underutilized or "lost" African grain crops might have tremendous potential. These grains are more fit or adapted than the introduced species for cultivation in their native areas and perhaps for introduction into other areas with similar geoclimatic characteristics. It should not be surprising that these crops do not yield as well as the world's premier grain crops under nonlimiting, low-stress conditions, because of the paucity of applied research conducted with these grains. The fact that they have the capacity to significantly outperform the introduced premier crops, and in fact produce a crop in situations where corn, maize, or rice can't even be grown to yield, makes a powerful statement about their value as an agricultural resource. The fact that they have unique qualities (particularly vis-à-vis malting and fermentation) that enable them to be used at the household level to produce high-quality, energy-dense weaning foods and therapeutic ORS alternatives should accord these grains premier status in the annals of tropical agriculture and nutrition. The issues highlighted herein and dealt with in considerable detail in the recent National Research Council report[7] must generate increased attention in the international nutrition community to focus the attention of scientists and policy makers on this mounting social dilemma.

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