

Biofortification of Sorghum

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Introduction

Hunger is one of the greatest challenges facing Africa, especially sub-Saharan Africa. Amidst the present pace of development one, particular set of people are always at the rear – the rural dwellers. The rural communities have the greatest population not only of the poor, but of illiterates. These illiterates lack the necessary capacity to overcome their difficulties or the ability to fully appreciate their predicament.

Current food aids that have come to be known as the trademark of Africa go a long way in relieving the plight of refugees, and, victims of war and famine. Yet, they are not an adequate solution for Africa's people. For one, they are not an empowering solution with a view to sustainability. Also, they fail in most cases to reach the rural communities who are the greatest victims of poverty. One reason for this is that the urban areas are the first ports of call (with its own poor population). Another is that the logistics of reaching distant rural communities poses a serious obstacle to the whole effort. Another problem arises from the sheer size of the ideal target population, which de-emphasizes adequate nutrition (through provision of essential vitamins and minerals) in favour of simple survival.

A new paradigm for agriculture in the 21st century was proposed that views agriculture as an instrument for public health and focuses attention on the role of agriculture in delivering nutrients to humans and animals in balanced amounts that can sustain maximal physical and mental activity of the humans who are simultaneously the drivers of the food system and its dependents.²⁷ **Biofortification** was the answer.

It is the process of breeding food crops that are rich in bioavailable micronutrients. The fortified crops are loaded with high levels of minerals and

vitamins in their seeds and roots, which can then be harvested for consumption. It is a novel concept that is providing a tangible solution to the dual issues of hunger and malnutrition among Africans. Industrial biofortification of common foodstuffs, such as iodized salt and those augmented with vitamin A (i.e. sugar) is a welcomed development. Biofortification is a current trend in thinking that provides a real time solution to health and hunger issues plaguing the poorest citizens of Africa, especially those in distant rural communities that have a tendency to be forgotten.

According to the International Food Policy Research Institute, more than 840 million people do not have enough food to meet their basic daily energy needs. They also stated that an estimated 3 billion suffer the insidious effects of micronutrient deficiencies because they lack money to buy enough meat, fish, fruits, lentils and vegetable. This means that the most vulnerable members of society, pregnant women and children would be unfairly predisposed to disease, premature death and impaired cognitive abilities because of diets poor in crucial nutrients. Biofortification of staple crops such as sorghum have the additional advantage of being a traditional African crop, easily identified by the local populations. It is cultivated on a subsistence level by farmers for human consumption and thus plays an important role in food security. Its cost of production is less than that for micronutrient supplements and industrial fortification. In addition, the culture shock from the introduction of food items or nutrition supplements foreign to their way of life is avoided. Instead, biofortification of sorghum represents a culture shift that can be easily assimilated by the vast population of illiterate, traditional, rural dwellers of Africa, in addition, to its urban population.

What is Sorghum (*Sorghum bicolor* (L.) Moench)?



Courtesy Syngenta Foundation for Sustainable Agriculture website

Sorghum is also referred to as kafir corn, milo, sorgos, durra, guinea corn and dawa. It is an erect cereal plant believed to have originated in the north-eastern quadrant of Africa, where the greatest diversity in wild and cultivated species is found. Experts believe it to have been domesticated between 5,000 and 7,000 years ago in modern day Ethiopia. From here it spread to the rest of Africa and to India along trade routes. From India it went to China via the silk trade, while, it reached the Americas courtesy of the slave trade.

It is taxonomically classified in the same family as maize, Gramineae. It is also classified under the sub-family *Panicoideae* and the tribe *andropogoneae*. There are two sub-species generally accepted sorghum bicolor and grass sorghum. Sorghum bicolor represents all the cultivated and wild forms of sorghum; while, grass sorghum represents the perennial weeds or those grown as forage.

Sorghum is also found in temperate regions and at altitudes of up to 2300 meters in the tropics. It also has the capacity to tolerate conditions of limited moisture and to yield in periods of prolonged drought. This characteristic sets it aside from other cereal crops that would die under the same conditions. It has morphological and physiological features that enable it adapt to dry conditions. These adaptations include:

- | an extensive root system
- | waxy bloom on the roots
- | reduced leaf area for transpiration
- | higher net photosynthesis compared to other cereals
- | the ability to remain dormant in drought periods and resume growth afterwards
- | the plant visibly grows only after the root system is well established
- | competes well with most weeds
- | leaves have a waxy coating and they can roll in to reduce transpiration, etc.

Like corn, sorghum can tolerate a wide range of soil and climatic condition; but, its yield under these different conditions is relatively constant.

Uses

Sorghum is an important contribution to the diet of many people. It is used to make unleavened breads, boiled porridge, couscous, popped grain and syrup (from sweet sorghum). It is also used in Nigeria and South Africa by Guinness plc to produce malted beverages and beer. All these uses would have improved nutritional value upon the use of a biofortified version of sorghum.

Sorghum can be used as a gluten-free replacement for wheat, but due to the lack of gluten sorghum breads are generally unleavened. Some varieties are rich in antioxidants. And except for the high-tannin sorghum, the flavor is neutral and the grain is known for taking on the flavors of the other ingredients²¹.

In addition, some Africans use the straw of sorghum to make palisades in villages or around a homestead. They can also be used in the production of brooms, baskets, fish traps and the plant bases are an important source of fuel for cooking materials. West Africans also use the dye extracted from sorghum to dye leather red.

Distribution

The red dots represent the sorghum producing countries in the world



Courtesy Syngenta Foundation for Sustainable Agriculture website.

In 1994, sorghum was ranked 5th among the most important cereal crops of the world (after wheat, rice, maize, and barley in both total area planted and production). Since then, the story has not changed.

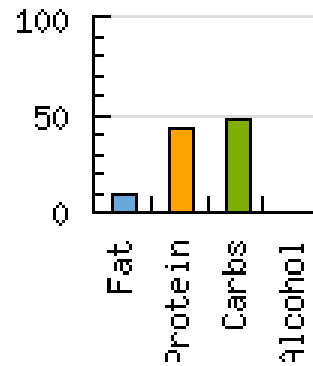
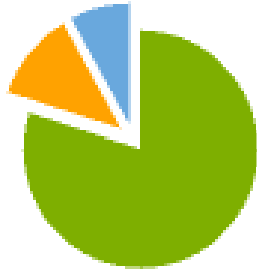
It is cultivated on 44 million ha in 99 countries in Africa, Asia, Oceania, and the Americas. The major producers are the USA, India, Nigeria, China, Mexico, Sudan and Argentina²². According to the Super Sorghum website, the world's top producer is the United States of America which produces 17% of the world's sorghum yield. Nigeria and India follow with 14% and as such are the world's second highest producers²⁰.

Eighty percent of the area devoted to sorghum is located within Africa and Asia, with average yields of 810 and 1150 kilograms per hectare, respectively²². The crop occupies 25% or more of arable land in Mauritania, Gambia, Mali, Burkina Faso, Ghana, Niger, Somalia and Yemen, and >10% of this area in Nigeria, Chad, Sudan, Tanzania and Mozambique.

Nutritional Value

Calorie Breakdown

Daily Values



Courtesy of Nutritional Facts website

Sorghum has a high carbohydrate content in the form of starch. The protein content is significant and comparable to that of wheat and maize, but its digestion is an obstacle to its nutritive value. It has a higher fat content than wheat or rice, but, is lower than that of maize. Its mineral content varies depending on the environment in which it is produced, and in most cases it is insignificant. Some varieties of sorghum have high dietary fibre content. Unfortunately this tends to have an adverse effect on the availability of some nutrients. Sorghum is also known to be a rich source of B-complex (β -carotenes), but its quantity also varies with the environment in which the sorghum is grown. Among its good points, sorghum is low in saturated fats has no cholesterol, is low in sodium and has no sugar.

Hindrance to crop improvement

In vivo, and *in vitro* studies indicate that the proteins of wet cooked sorghum are significantly less digestible than the proteins of other similarly cooked cereals such as wheat and maize. This difference as a result of the cooking process inadvertently creates a constraint on the use of sorghum for human consumption and implications on the food security in regions depended on it.

There are various reasons for this, which can be classified into two broad categories of hypotheses⁹. They are namely: exogenous and endogenous factors.

The exogenous factors include:

1. Grain organizational factors: Doudu et al. (2002) illustrated how the removal of the three main levels of organizational structure, namely whole grain, endosperm and protein bodies resulted in improved protein digestibility.
2. Polyphenols: Chiber et al. (1920) demonstrated that in high-tannin sorghum varieties, formation of indigestible protein-tannin complexes is

a major limiting factor on protein utilization in sorghum. The tannin-protein interaction in sorghum involves hydrogen bonding and hydrophobic interactions². Sorghum prolamins (proline-rich proteins) therefore bind strongly to sorghum tannin and this result in reduced protein digestibility.

3. Phytic acid: The phytate molecule containing six phosphate groups is highly charged. Ryden et al. explained that this phenomenon allows for the formation of insoluble complexes with proteins.
4. Cell wall component: Proteins have been shown to associate with pericarp or endosperm cell walls in sorghum ¹². It is suggested that such an association could lower protein digestibility either by reducing the accessibility to enzymes or the formation of indigestible complexes⁹.
5. Starch: It has been shown that treating cooked sorghum samples with *alpha*-amylase prior to incubation with pepsin leads to an improvement in *in vitro* protein digestibility⁶. This is an indication that gelatinized starch could reduce the accessibility of proteolytic enzymes to protein bodies and therefore reduce protein digestibility.

The endogenous factors include:

1. Disulphide crosslinking : When sorghum is cooked, enzymatically resistant protein polymers are formed through disulphide bonding of *beta*- and *gamma*-kafirins, Oriá et al. This is perhaps one of the most important factors contributing to reduced protein digestibility of cooked sorghum. These disulphide cross-linked proteins prevent access to and restrict digestion of the more digestible and centrally located *alpha*-kafirin within the protein body¹³.
2. Kafirin and zein hydrophobicity : Relatively higher hydrophobicity of kafirins compared to zeins has been suggested to be a possible factor affecting sorghum protein digestibility ⁹. Hydrophobic proteins would be expected to have lower enzyme accessibility since enzymes function in an aqueous environment.

Prospects of crop improvement

Sorghum does not have a diverse range of genes available for cross breeding in its genetic pool. This makes it difficult for nutritional improvement of sorghum via traditional selective plant breeding. There are only two mutant high lysine genes are currently available, the spontaneous mutant gene *hl* which was initially identified in an Ethiopian line¹⁹ and the *P721 opaque* gene which was induced with ethyl methane sulphonate (EMS)¹.

On the other hand, modern biotechnology has empowered breeders with the necessary tools thru genetic engineering. Genetic engineering will allow for the introduction of wild or mutant genes from other organisms. There are five basic tools of technology has been developed for sorghum improvement:

1. *in vitro* protocols for efficient plant regeneration;
2. molecular marker;

3. gene identification and cloning;
4. genetic engineering and gene transfer technology to integrate desirable traits into the sorghum genomes; and
5. genomics and germplasm databases¹⁷.

Within the last decade there has been the production of transgenic sorghum plants via particle bombardment of immature zygotic embryos²⁶, immature inflorescences³, and shoot tips²⁶. Also the year 2000, saw the production of transgenic sorghum plants via *Agrobacterium*-mediated transformation using immature zygotic embryos as explants²⁸. Also Tadesse in his post doctoral thesis introduced a functional gene which codes for the first enzyme of the lysine-specific pathway into the genome of sorghum. His goal was the production of a transgenic sorghum with high lysine levels.

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