A FOOD CHAIN APPROACH TO HEALTHY NUTRITION WITH TRADITIONAL GRAINS IN THE NORTH AND SOUTH MARKET

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INTRODUCTION

Wageningen University has a tradition in agriculture and life sciences research. During the past decade, increasing emphasis is given to interdisciplinary research programmes dealing with complex issues. The INREF (Interdisciplinary Research and Education Fund) functions as a platform for interdisciplinary research projects, carried out in collaboration with institutions from the South. These projects serve as a training ground for PhD and MSc students from North and South, and are usually co-financed from external sources. This presentation deals with some of the issues resulting from the project: "From natural resources to healthy people: Food-based interventions to alleviate (micro)nutrient deficiencies". The food chain plays a central role in this project, as is illustrated in Figure 1.

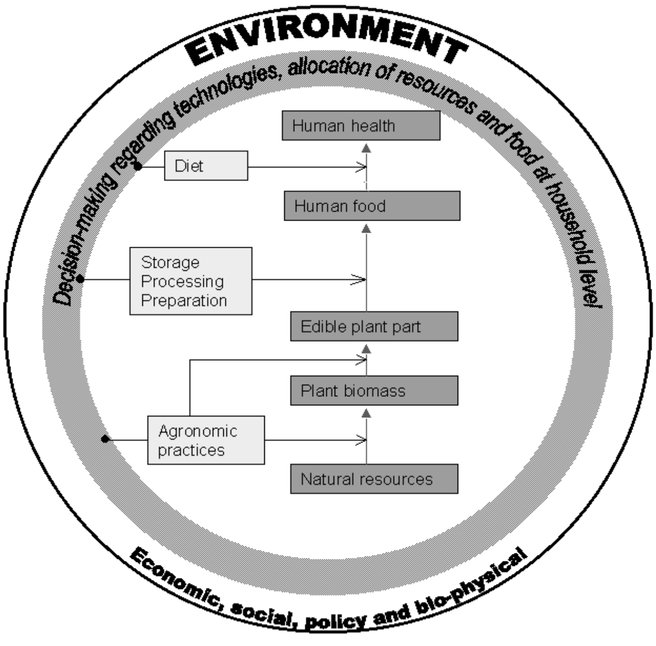

Figure 1. The Food Chain (Slingerland et al., 2006)

The food chain includes primary production, post-harvest processing and handling, food consumption and nutritional outcome, all within the context of a societal environment. The latter provides numerous opportunities and constraints of economical, cultural, social, political and bio-physical character.

As a final result, the nutritional outcome is of great importance. In this respect, we consider a "healthy nutrition" as a dynamic balance at the individual level, of intake and requirements of nutrients.

TRADITIONAL GRAINS IN THE NORTH AND SOUTH MARKET

Of the range of traditional (cereal) grains from North and South, we will focus on a major and minor cereal from each region.

In the North, wheat (*Triticum* sp.) is a major grain and its production extends to some of the Southern regions providing that climate and soil conditions permit its cultivation. Wheat is categorized as soft (used in biscuits), medium (baked goods including breads) and hard (used for pasta). Oats (*Avena* sp.) is a minor cereal which is mainly processed into rolled oats for porridge making.

In the South, rice (*Oryza* sp.) is a major cereal grain and is usually categorized as short-, medium- or long-grain rice. There are many ways of processing rice but most rice is milled and polished into white rice. White rice is used as a staple food almost all over the world. A minor crop of the South is sorghum, sometimes named guinea corn, (*Sorghum* sp.) and this grain has various food-uses (FAO, 1995) such as porridges, gruels, beers, and liquors (Haard et al., 1999). In addition, in some regions sorghum is grown for animal feed purposes. As shown in Table 1, the world production (estimated 2004 FAO-data) of wheat and rice is of a comparable level, followed by sorghum and oats. Whereas these grains all constitute a basic dietary source of energy, protein, fiber, minerals and vitamins, it is obvious that the starch/protein ratio in oats and wheat is significantly higher than in sorghum and milled rice.

Table 1. World production and macronutrients of wheat, oats, rice and sorghum (FAO, 2007).

	World production (x 10^6 tons)	Crude protein (avg, %)	Fat (avg, %)	Starch (avg, %)
Wheat (whole)	613	16	2	60
Oat (hull-less)	25	18	5	56
Sorghum (endosperm)	65	12	0.6	82
Rice (milled)	608	7	0.4	82

ROLE OF GRAINS IN NUTRITION

The composition of typical Northern and Southern diets is different; better economic situations in the North allow higher consumption of animal-derived foods and fats, whereas cereal grains play a much more prominent role in Southern diets. In addition, lifestyles and living conditions may differ considerably, resulting in different types of - sometimes extreme - nutritional outcomes, including severe obesity in contrast with starvation.

While world-wide, about 800 million people suffer from hunger, even more suffer from micronutrient malnutrition particularly of Iodine, Vitamin A, Iron and Zinc. These deficiencies may result in e.g., impaired mental development, goitre, cretinism, reduced immunity, anemia, stunting, and nightblindness (Slingerland et al., 2005). The negative consequences for public health, work productivity and national development are significant.

To increase the effective supply of micronutrients, the diet should contain levels of micronutrients exceeding the recommended uptake. For example, it has been observed that in plant-derived diets, only 5-10% of Fe is available for metabolic uptake, because the remaining Fe is bound into insoluble and indigestible chemical complexes with e.g. phytic acid or polyphenols. Micronutrients must not only be present, but they must be available (absorbable) and effective (convertable into a bio-active form) (Slingerland, 2007).

FOOD CHAIN BASED APPROACH

Our project studied how pre- and post-harvest events along the food chain may influence the levels and bio-availability of (micro)nutrients from grains, and how their intake may be influenced by food habits and interventions. Some specific outcomes will be discussed to illustrate the approach.

In rice, Zn fertilization was carried out to measure the Zn response in the rice kernel. Under field conditions we seem to be able to lift grain Zn levels from 15 mg Zn kg-1 grain to 30 mg Zn kg-1 grain but not more (Xiaopeng et al., 2006). Toxicity can be reached under solution culture but levels of Zn needed for this are so high these would not be reached under any normal soil condition. While in pot studies we were able to reach 50 mg Zn kg-1 grain and in solution culture we were able to reach up to 90 mg Zn kg-1 grain (data to be published) such levels are not possible under poor zinc delivering soils. On acid soils we may be able to reach 50 mg Zn kg-1 grain. This could be representative for some more tropical areas of Asia.

When comparing sorghum cultivars for breeding purposes, it was observed that phytic acid and polyphenols may be negative factors from human nutrition point of view (Dicko et al., 2006), but that they also serve important functions in the seed. For example, phytic acid is an important store of Phosphorus, and is required for germination and establisment of the plant. Polyphenols protect against predators (insects, birds, fungi) and regulate germination (Stomph et al., 2006).

The next step in the food chain is the processing of grains into foods. The suitability of sorghum cultivars for food preparation shows a large diversity (Kayode et al., 2005,Kayode et al., 2006,Yetneberk et al., 2004). We studied the effects of unit operations such as washing, grinding, sieving, germination, fermentation and cooking of sorghum which are involved in the preparation of products such as porridge (Kayode et al., 2007c) and beer (Kayode et al., 2007b). In Bénin, the process of making dibou porridge revealed that only minor quantities of phytic acid and polyphenols are removed by the regular household process (Table 2), which resulted in low bioavailability of Fe and Zn (data not shown). In contrast, tchoukoutou beer making resulted in considerable degradation of phytic acid with considerable increase of soluble Fe (Kayode et al., 2007a). Further technological experiments will be required to improve the reduction of phytic acid in sorghum flour for porridge making (Taylor et al., 2006).

Table 2. Phytic acid levels during sorghum dibou porridge preparation scenarios (Kayode et al., 2007c).

	Scenario 1	Scenario 2	Scenario 3
Grain	1.0 ± 0.1	1.0 ± 0.1	1.0 ± 0.1
Cleaned grain	1.1 ± 0.2	1.1 ± 0.2	1.1 ± 0.2
Sieved flour	n.a.	1.1 ± 0.2	1.2 ± 0.1
Cooked	0.9 ± 0.1	1.0 ± 0.1	1.1 ± 0.2

All data as % dry basis. Scenario 1: dry cleaning, grinding, cooking; scenario 2: dry cleaning, grinding, sieving,cooking; scenario 3: wet cleaning, grinding, sieving, cooking.

We also studied the ranges of minerals and phytic acid levels in Chinese rice cultivars. Variability of genetic and agronomical factors result in crops that combine high minerals and low phytic acid levels (Liang et al., 2007). Nevertheless, further processing is required to reduce phytic acid and to achieve sensory acceptability for the consumer. We observed that although minerals and phytic acid have different spacial distributions in rice, milling and polishing cause very high losses of nutrients (to be published).

In both sorghum and rice, we conclude that although processing for phytate removal can be successful, the present mineral levels in the processed grain are too low for nutritional purposes (Ma et al., 2005).

Because of the low mineral content and the presence of complexing factors, fortification is highly advisable. This could be approached through various avenues depending on the target mineral. For example, in Sorghum the grain Zn levels could be easily increased to 70 mg/kg by Zn fertilization. This appears to contrast with the rice data showing there may be much more promising short term solutions in Sorghum in the Sahel (acid soils) than in rice. Breeding always takes a long time and fertilization will always be needed to replenish the soils and provide the Zn that plants are able to take up.
For Fe the story is much more gloomy. Whereas Fe is always plenty in soils, plants simply avoid Fe-toxicity by very low uptake; hence, only breeding or bio-fortification are options. During post-harvest processing, food enrichment offers short-term solutions.

For post-harvest fortification a number of requirements must be fulfilled (Baltussen et al., 2004,Hurrell et al., 2004). First, the added micronutrient must be food-grade and have a good bioavailability also during storage; the fortificant should have no negative effects on sensory acceptability (flavour, colour), should be easy to process (dry blending, spray coating) and should be commercially available at an affordable price. Successful examples are the use of FeSO4 in wheat flour and FeNaEDTA in fish sauce (Walczyk et al., 2005).
Fortification with imitation rice containing high Fe levels has been advertised (Anon, 2007). This rice will be mixed through regular milled rice. The product will be test-marketed soon in China.

Fortification (Slingerland, 2007) by breeding can be carried out to achieve increased mineral levels (e.g. Fe in rice from 13 to 38 ppm), or increased levels of functional components such as heat-stable phytase, or beta-carotene. To achieve the latter two goals, genetic modification is required (Vasconcelos et al., 2003). While the GMO-technical procedures are available to achieve these goals, it takes several years to produce a novel crop, once it has been approved for introduction at market level . In future, challenges relating to the consumer acceptance of GMO-foods, the processor acceptance of new breeds with different properties, and the distribution of seed to small-scale farmers, need to be addressed.

OUTLOOK

The impact of the food chain on the nutritional outcome of cereal grain consumption is highly complex. Mathematical modelling approaches will be required to evaluate the nutritional outcome as influenced by interventions at pre- or post-harvest level. Some approaches at post-harvest process technology level have been made (Wolters, 1992); these have a rather limited scope and need to be expanded and further developed.

The nutritional role of grains in northern and southern diets may be quite different, especially regarding the need to supply dietary fiber (North), and nutrients such as protein, energy, iron and zinc (South). This has important implications and opens opportunities to dedicate food chains for temperate and tropical grains to the requirements of the end-user.

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