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USE OF DRIED KAPENTA (*Limnothrissa miodon* and *Stolothrissa tanganicae*) AND OTHER PRODUCTS BASED ON WHOLE FISH FOR COMPLEMENTING MAIZE-BASED DIETS

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ABSTRACT

Poor nutritional status both for children and adults is highly prevalent in those parts of sub-Saharan Africa where maize is a dominant staple. Maize is not a complete food, and if the child's diet is only based on white maize, it may be deficient in calcium, vitamin A, vitamin C, vitamin B_{12}, vitamin E, vitamin K, folate, riboflavin, pantothenic acid, niacin, potassium and iron. Inadequate intake of essential amino acids, vitamins, minerals and trace elements is associated with reduced growth, weakening of immunological functions and enhanced morbidity and mortality from infectious diseases, including measles, diarrhoeal diseases, parasite infestations, tuberculosis and HIV disease. Pregnant women and people suffering from infectious diseases, including HIV and tuberculosis, need a diet rich in protein and micronutrients. During pregnancy, growth requirements for the foetus must be covered. Infections lead to significant metabolic changes with enhanced rates of degradation or excretion of several nutrients including total protein, essential amino acids and vitamins. The diet must now contain higher amounts of nutrients than required by a healthy child or adult person in order to prevent the development of protein malnutrition and micronutrient deficiencies that will in turn easily lead to weakening of immunological functions. The purpose of the study was i) to analyse the nutrient composition of kapenta, and compare it to other animal products, and ii) to calculate the quantity of these products needed to cover the recommended dietary intake of several nutrients. Nutrient compositions of whole dried kapenta and Norwegian fish powder (fish protein concentrate type B) were found to be similar. It is shown that products made from whole fish are qualitatively superior to fish fillet and other animal products because they are much better sources of minerals and trace elements such as calcium, iron and zinc. They are also good sources of vitamin B_{12} and other bioactive substances such as membrane lipids, taurine and nucleic acids. Calculations of the improvements in nutrient intake if a maize-based diet is supplemented with minor amounts of a micronutrient- and protein-rich food like dried kapenta, or fish meal, was shown to give a balanced diet covering most of the nutrient requirements. It should be noted that patients suffering from chronic infectious diseases such as AIDS and tuberculosis have higher nutrient requirements (for protein, essential amino acids and several micronutrients) compared to healthy persons.

Key words: Nutrition, children, maize, kapenta, fish-meal

INTRODUCTION

The poor nutritional status of the population in many parts of Africa is worrying. This fact is reflected in a baseline survey report carried out in 2001 from 304 households in the Iringa and Morogoro regions in Tanzania which showed that more than 80% of the children below five years were anaemic, while 25% and 52% were underweight and stunted, respectively [1]. For people over 15 years of age, the prevalence of anemia was approximately 50% with higher incidence for women. Anthropometric measurements showed that about 10% of the adult females were underweight, as compared to 31% of the males. The proportion of children and adults who were severely wasted were 1.5% and 4%, respectively.

In the villages surveyed, the most common type of dish was stiff porridge from maize flour. The second most common dish was rice. The main dishes (stiff porridge or rice) were usually eaten with only one type of relish: beans, or sardines, or other fish, or green leafy vegetables. Cassava was consumed only when there was severe shortage of maize. Sorghum was eaten less commonly than maize. Often it was sold to get money, which was then used to buy maize flour. Food preservation was not widely practised.

Several forms of malnutrition are widespread in sub- Saharan Africa, not only because of widespread poverty, but also because the soils can be depleted in several important nutrient elements, such as iodine, selenium, sulphur and zinc. Protein malnutrition is even more prevalent in countries and districts where the main staple food is cassava, rather than maize [2,3]. Inadequate intake of protein or of micronutrients such as vitamin A, vitamin B_{12}, iron, zinc and selenium is associated with weakening of immunological functions and enhanced morbidity and mortality from several infectious diseases, including measles, childhood diarrhoea and tuberculosis [4,5,6].

The infections, in turn, lead to significant metabolic changes with substantial enhancement of the rate of degradation or excretion of several important nutrients, including total protein, sulphur amino acids, tryptophan and various vitamins [4,7,8,9]. Infectious diseases, therefore, cause exacerbation of protein- energy malnutrition and various vitamin deficiency disorders associated with poor diets [4]. A good diet (with substantially higher protein and vitamin intake than needed by a healthy person of the same sex and age) can compensate for much of the metabolic effects of infection (except for acute infectious episodes associated with high fever and loss of appetite). This is especially important in connection with chronic infections, such as HIV disease and tuberculosis. It is well documented that malnutrition associated with these diseases can be treated and reversed with a good, protein-rich diet [10,11]. This is important not only for preserving immunological functions and preventing the death of HIV or tuberculosis patients as a direct consequence of severe protein- energy malnutrition, but also for preserving the muscle strength and endurance and hence the working capacity of HIV-infected farmers as long as possible, thus helping to reduce the impact of the HIV epidemic on food production in Africa

It is therefore of vital importance that agricultural and medical scientists (as well as Earth scientists) can collaborate, in order to find sufficiently cost-effective and also ecologically sustainable methods to provide for African HIV and tuberculosis patients the type of diet that they need in order to correct several forms of malnutrition that without correction will lead to aggravation of the disease, and also for testing the effect of suggested improved diets on patients. Improving the quality of the diet for a majority of African HIV and tuberculosis patients to provide what they need is a gigantic task that still remains to be solved, and it is hardly possible to see how this can be done on a continent-wide scale in Africa unless both the agricultural and fisheries sectors must take their part.

In Norway, starch-rich foods have traditionally been combined with animal foods, such as milk, meat or fish. During the late 1960s, a project trying to make high-quality, food-grade–fishmeal from whole sea fish (fish protein concentrate type B, FAO classification, or in short FPC type B) was started in Norway at the initiative of the Norwegian Church Aid. This initiative was soon followed up by the Norwegian National Nutrition Council/Norwegian FAO Committee, as well as by politicians from different parties in successive Norwegian governments and parliaments. For about one decade from 1972, Norwegian FPC was used by several different NGOs and the World Food Programme as emergency food aid during famine and civil war situations as well as for support of refugees. However, this was stopped after the type of raw material had been changed from species such as capelin and sprat that had an exceptionally high total content of natural antioxidants and co-antioxidants (such as anserine, spermine, trimethylamineoxide and taurine) to species with lower (and more normal) antioxidant content. The storage stability of the product became much poorer than before, and the producers did not understand that it was necessary to store and pack it in a protective atmosphere to avoid oxidative rancidification.

The product is still available in Norwegian health food shops. It is now packed under inert gas in airtight and light-shielded bags made from aluminium-plastic laminate. It is rich in essential amino acids, vital lipid components, minerals and vitamins, but also in conditionally essential nutrients such as nucleotides and taurine, which may be in short supply and therefore can be of therapeutic value (for example for pain reduction, anti-ischemic protection or immunostimulation) in several disease situations [6,12,13]. It can be theoretically expected from what is known (from studies both in animals and humans) about the effects and dose-effect relations of individual components that various essential and conditionally essential nutrients found at high levels in products made from whole fish often will interact synergistically with each other for anti-thrombotic, anti-ischemic, anti-arrhythmic and anti-inflammatory protection. These synergistic interactions typically lead to sigmoid dose-response curve for the therapeutic effect as a function of the ingested daily dose of whole fish.

The study reported here was carried out as part of a research project initiated by the Kenneth Kaunda Children of Africa Foundation with partners of scientific collaboration in several countries including Tanzania and Norway. One of the main

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objectives of this project has been to find practical ways for improving both the therapeutic ratio (which for our purpose can be defined as the ratio between Σ(magnitude x frequency) of desired therapeutic effects and Σ(magnitude x frequency) of negative side effects) and health economic cost-effectiveness of AIDS therapy in Africa through dietary intervention, using foods that are at the same time both nutritious and cheap. More complete reports of the results from these still ongoing studies will be published elsewhere, but some of the main conclusions from work already done can be reported here.

Earlier reports that protein-energy malnutrition in AIDS patients can be reversed by protein-rich (and micronutrient-rich) diets [11] even in the absence of antiretroviral drug therapy, provided that the absorptive intestinal function is not too severely impaired [11], have been abundantly confirmed in these studies. A striking observation has been the strong dependence of the risk of highly serious and even lethal side effects of antiretroviral drugs on the nutritional status of the patient. This is a problem that has apparently not received as much international research attention as we believe it deserves (one reason perhaps being that it might be less prevalent in affluent patient populations in industrial countries than in Africa), and it is in our view very important in the practical clinical management of AIDS patients in poor countries. The strategy is now to start with nutritional rehabilitation of the patients and postpone the start of antiretroviral drug therapy until the nutritional status of the patients has become sufficiently improved that the patient can safely tolerate the drugs (when considering only the problem of acute toxicity, and not the long-term side effects that can develop because of the mutagenic effects of many of the drugs concerned, with the latter now being very well-documented from numerous animal experiments). This strategy has given very encouraging results.

Both FPC from Norway and a soy-based product from South Africa that is marketed there for prevention and therapy of malnutrition in children and which is fortified with several micronutrients, including selenium, have been tried for this purpose in hospitals and at out-patient clinics for AIDS patients in Zambia, in both cases with highly satisfactory results. The study was not designed for testing which product is the better one, and the only conclusion one can make is that both products can be used for achieving the desired therapeutic effects. There is from a theoretical point of view good reason to expect that several other foods or food combinations also can be used to achieve similar clinical results, and the agricultural universities both in Tanzania and Norway are now engaged in research projects, trying to make this possible with other protein-rich food products (including milk from high-yielding dairy goats) that can be produced locally at an acceptably low price in village communities in Africa.

Although important, FPC imported from Norway is now fairly expensive, and locally produced substitutes are, therefore, needed.

Hence, the objectives of this study were to compare the nutritional value of a dried small fresh water fish (kapenta, available on markets in countries like Tanzania and Zambia) with FPC imported from Norway, and test how maize-based diets can be improved by complementing them with dried kapenta or other products made from whole fish.

MATERIALS AND METHODS

Samples of small dried fresh-water fish named kapenta (*Limnothrissa miodon* and *Stolothrissa tanganicae)* were purchased at a local market in Lusaka, Zambia and brought to Norway for chemical analysis. In Zambia this fish (which belongs to the same family as herring and sardine) is known as kapenta, but elsewhere it is known as *Dagaa* or *Ndgaa*.

The kapenta was ground into a powder before analysis. A sample of Norwegian fish protein concentrate type B food-grade fishmeal was analyzed. This sample had been produced by Seagarden, Karmøy, Norway, which is a factory specially constructed for making FPC type B, and is marketed in Norway by the company Arctic Health Products (address: 5341 Straume, Norway). Both products were analyzed at a commercial analysis laboratory (Analycen, Moss, Norway) using reference methods EU DIR 71/393m (water) [14], EU DIR 93/28m (protein) [15], EU 98/64 (cysteine, methionine, aspartic acid, threonine, serine, glutamic acid, proline, glycine, alanine, valine, isoleucine, leucine, tyrosine, phenylalanine, histidine, ornithine, lysine, arginine, hydroxyproline, tryptophan, and taurine) [16], NS-EN ISO 11885 (iron) [17] and AOAC 952.20/45.2.02 (vitamin B_{12}) [18].

Table values were used for the other foods discussed in this paper. They were taken from USDA food tables, from a study of the mineral nutrient composition of all important foods in Finland [19], and from a Norwegian study of the composition of fishmeal made from several different species of fish [20].

RESULTS

As shown in Table 1, the nutrient composition of kapenta and Norwegian FPC type B were remarkably similar. The protein concentrations in dried kapenta and FPC are both high, being 72.9 % and 72.8 %, respectively. The concentrations of the amino acids cysteine, methionine, aspartic acid, threonine, serine, glutamic acid, proline, glycine, alanine, valine, isoleucine, leucine, tyrosine, phenylalanine, histidine, ornithine, lysine, arginine, hydroxyproline, tryptophan and taurine were nearly identical in kapenta compared to FPC (Table 1). The iron concentration was also nearly the same in kapenta and FPC; 72 and 77 mg/kg, respectively. The concentration of vitamin B_{12} was somewhat higher (28% higher) in FPC compared to kapenta (Table 1).

In Table 2, the concentrations of several nutrients in 100 g maize flour (whole grain, white) are shown. The values are taken from the USDA food composition table [21]. They correspond to, or are somewhat higher than values found in the Norwegian food table, the Pacific Islands food composition table and the food composition table for use in Africa. The USDA table was chosen because it has included concentrations of individual amino acids. In Table 2 the estimated requirements (official dietary guidelines) for children 1-3 years are shown [22]. One hundred grams of maize flour provides about 31% of the child's daily food estimated energy requirement. Corresponding figures for percentage coverage of estimated daily requirements from 100 g maize are shown for several nutrients, but without adjustment for bioavailability. From the table it is can be seen that white maize flour is deficient in vitamins A, E, K, C, B_{12}, riboflavin, folate, as well as in calcium and potassium.

From Table 3, the concentrations of lysine and tryptophan as percentage of total protein in maize flour, (USDA, whole grain, white) may be calculated, and lysine and tryptophan, as percentage of total protein is 2.8% and 0.7%, respectively.

In Table 4, the concentrations of protein and some nutrient elements (nitrogen, calcium, phosphorus, magnesium, iron, iodine, selenium, zinc and fluoride) are shown for fishmeal, skimmed milk powder, beef, pork, cod and salmon. This table shows that FPC (having the same composition as fishmeal) is a more complete (or well-balanced) source for these nutrients compared to all the other animal foods shown in this table.

Table 5 shows the quantities needed of fish powder (FPC type B), skimmed milk powder, beef, pork, cod and salmon to cover the daily requirements [22] in a child 1-3 years old for nitrogen, calcium, phosphorus, magnesium, iron, iodine, selenium, zinc and fluoride. The table shows that a relatively small amount of fish powder will meet the estimated requirements for all these nutrients. But for all the other animal products shown, surprisingly large quantities are needed for some of the nutrients concerned, with milk being highly deficient in iron, while meat is highly deficient in calcium, and fillets from cod or salmon are highly deficient in calcium, iron and zinc, but good sources for selenium and iodine.

It can be seen from the calculations in Table 5 that if a child's diet is supplemented with 10-20 g FPC type B or dried kapenta, it will meet most of the nutrient requirements (being vastly superior to a diet based on maize alone), but not all, since vitamin C, vitamin A and vitamin E will still be in short supply.

DISCUSSION

Vitamins and minerals in maize

It can be seen from Table 2 that a diet consisting only of whole-grain white maize is highly deficient in calcium and vitamins A, E, K, C, B_{12} and folate, and moderately deficient in riboflavin and potassium. Mineral and vitamin deficiencies following a monotonous maize-based diet depend, however, both on cooking methods (especially for niacin, zinc and iron, for reasons that will be explained below) and on soil composition variables that can be very different in different geographic areas, for reasons that are well explained in several geochemistry and soil science textbooks, with iodine [23], selenium [24] and zinc [25] being especially important examples. The intestinal absorption of niacin, iron and zinc from whole-grain maize depends strongly on the methods of food preparation. Most of the niacin content of maize is present in a form poorly available for intestinal absorption unless the maize has been treated with alkali (in form of calcium hydroxide or plant ashes), as was commonly done in America before Columbus [26]. When plant ashes were used for this purpose, or for counteracting the antinutritional effect of tannins in acorns [26], it would help to counteract iron and zinc deficiencies as well. The iron and zinc content of whole-grain maize flour is poorly available because intestinal absorption is inhibited by phytate [27,28]. For zinc, it must also be expected that there will be much geographic variation depending on variations in the zinc concentration of the soil as well as in the bioavailability of zinc in the soil for uptake in the plant roots (depending on soil pH, cation exchange capacity and calcium concentration). Much of the maize grown in Africa is probably more zinc-deficient than maize grown in the United States because severe zinc depletion in the soil is much more widespread (and more pronounced) in Africa, especially in areas with highly weathered tropical soils, than in the United States. Because of these factors, it must be expected that monotonous maize-based diets in sub-Saharan Africa very commonly will be deficient in niacin, iron and zinc as well.

Maize cultivation is much more recent in Africa than in America, and the methods that were used in America before Columbus for improving the bioavailability of niacin from maize might either have been unknown in much of sub-Saharan Africa, or this skill has been lost for most of those Africans who now rely on maize as their staple food [29]. Similarly, the knowledge of advantages of fermentation or germination as methods for improving the bioavailability of zinc and iron from maize for intestinal absorption has in many places been lost, partly due to urban migration and also due to the intergenerational knowledge gap. Yellow maize is a good source of *beta*-carotene (provitamin A), while white maize is not. The majority of the people in sub-Saharan Africa are, however, unaccustomed to eat yellow maize as was the case in Zambia and Tanzania (in the late eighties) when the yellow maize donated by the United States was rejected by most households in favour of the white variety. Nutritionally, the yellow maize was better, but acceptability was a major problem in Zambia and Tanzania. Much of the vitamin and essential trace element content of whole cereal grains are contained in the germ and bran. These fractions are, however, removed during industrial milling and are instead used as animal feed.

The deficiency most typically associated with maize consumption (more than with other cereal grains) is niacin deficiency, which if severe presents as pellagra. Pellagra is also common in patients who are in the late stages of HIV/AIDS in Africa. It is possible that part of the explanation for this could be enhanced degradation of tryptophan to products other than niacin following virus- and/or cytokine-induced induction of the enzyme indole-2,3 dioxygenase (IDO) in leukocytes [30], and also intestinal malabsorption. Pellagra is endemic in parts of Africa and can assume epidemic proportions during drought seasons. This condition was observed by Kinabo and collaborators in a study from 2001 in communities in Iringa regionin Tanzania [1] and was more prevalent during the dry season immediately after harvest and disappeared during the lean season when maize stocks are depleted. This is related to the processing of maize flour. During the dry season maize processing involves decortication to remove the bran, soaking in plenty of water for three days, sun drying and milling. When maize stocks are depleted (lean period of the year) maize is milled whole and, therefore, the consumption of whole meal maize increases. This is the time when the problem of pellagra subsides.

Phytate reduction
Whole cereal grains contain much phytate, which inhibits the intestinal absorption of iron, zinc and calcium. Much of the phytate is removed during production of refined cereal products, but this process will also take away much of the iron and zinc. It is, therefore, better if phytate can be removed by other methods, for example by fermentation processes [27,29] or by germination of the seeds (for seed types that will not produce toxic substances such as cyanogenic glycosides during germination, which can happen with some sorghum varieties). The Kenneth Kaunda Children of Africa Foundation has attempted in some previous and ongoing projects to re-introduce fermentation of maize among its clients living with HIV/AIDS. Improved skin appearance was observed in some of the patients after they had started to eat the fermented maize. It should be noted that not only niacin deficiency, but also zinc deficiency can lead to skin symptoms [27]. It is therefore difficult to know, in the absence of laboratory confirmation, if the patients concerned had been more severely deficient in zinc or in niacin (pellagra), and what was the actual cause of their skin symptoms. It is also possible that the fermented maize may have helped to correct intestinal malabsorption for niacin and zinc by functioning as a better source of nucleotides (in form of bacterial DNA and RNA) compared to unfermented maize, thus permitting faster DNA synthesis and hence faster growth of the cells of the intestinal mucosal epithelium.

Protein and amino acids
Compared with other cereals, maize has a medium protein/energy ratio: better than for rice, but not as good as for pearl millet. The traditional maize varieties are deficient, however, in the essential amino acids lysine and tryptophan. The lysine and tryptophan concentrations in normal maize whole flour are reported to be on average 2% (range from 1.6 -2.6 %) and 0.4% (range from 0.2 – 0.5%), respectively. The limitations in lysine and tryptophan in maize is caused by their high concentration of the storage protein zein, which is deficient in these amino acids. Modern maize varieties, which contain more lysine and tryptophan are now available, having 4% and 0.8% lysine and tryptophan in Quality Protein Maize [31].

In families subsisting on traditional maize varieties, lysine and tryptophan will normally be the first limiting essential amino acids if the child is eating only maize porridge. However, when the soil is deficient in sulphur, it is possible that sulphur amino acids may become limiting as well, since the concentrations of sulphur amino acids in cereal proteins depend on the concentration of sulphate in soil, and the concentrations given in an American food composition table may not necessarily be representative for those parts of Africa, where soils are often depleted in sulphur [32,33].

Polished maize is popular; increasing demand

In order to meet the increased demands for maize meal, large industrial-scale mills have been established. In addition, the technology for highly polished maize meal has become popular and spread rapidly in most countries in Africa. Polished maize, however, is markedly depleted in several micronutrients compared with corresponding non-refined products. The industrial milling of highly polished maize has, therefore, compounded the nutritional problems associated with maize.

Combining plant food and animal foods

As shown in Tables 3 and 5, supplementation with 10-20 g FPC type B or dried kapenta, to a child's diet will meet most of the child's nutrient requirements. However, vitamin C, vitamin A and vitamin E intakes will not be sufficient. Adding green leafy vegetables, fruits and unrefined red palm oil (which is an exceptionally good source of *beta*-carotene and also a good source of vitamin E) in sufficient quantities can help to meet the requirements for these vitamins as well. It should also be noted that the bioavailability of iron and zinc is much better for products based on whole fish than for phytate-rich maize.

Comparing plant and animal foods more generally, it can be seen that children normally need a combination of animal foods and plant foods in order to cover their requirements for all micronutrients and all conditionally essential nutrients. A suitable combination of plant foods can cover dietary requirements for most of the essential trace elements and vitamins, but vitamin B_{12} is a notable exception. It comes almost only from animal foods (with exception of some marine algae and certain fermented products). Iron and zinc are partial exceptions, since they are found in many plant foods, but often in a form poorly available for intestinal absorption (because of high concentrations of inhibitory factors with phytate inhibiting both iron and zinc absorption, and polyphenols inhibiting non-heme iron absorption), and iron and zinc from animal foods are much better absorbed [27,28]. Iron and zinc are much more unevenly distributed in different types of animal foods than is commonly realized (Tables 4 and 5). Dark meat and offal are excellent sources both for iron and zinc, while myoglobin-poor fish fillet (for example cod fillet) contains very little. Dairy products are good sources of zinc, but contain very little iron. It should be noted that meat and fish products also help to promote the intestinal absorption of zinc and non-heme iron from plant foods [27,28]; fresh milk has a similar effect for zinc, but not for iron.

Animal foods are also important as sources of dietary protein, which is found at high concentrations and has a good quality in terms of digestibility and essential amino acid composition. This is especially important for people suffering from infectious diseases including HIV, tuberculosis and malignant influenza (as demonstrated by the large geographic variation in mortality during the Spanish Flu pandemic), due to the combination of high protein/amino acid degradation and large requirements for some of the amino acids (notably glutamine and sulphur amino acids, but also others) in order to obtain an optimal immunological response [4,6,7,8,9,10,11]. Several animal

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foods, but not all, can also be important sources of various conditionally essential nutrients, such as nucleic acids and taurine, and of lipid components such as long-chain polyunsaturated fatty acids, *myo*-inositol and choline.

The total abundance of zinc in animal organisms is higher than for any other essential trace element except iron and perhaps silicon. The total amount of zinc in a human organism is normally about 60% of the total amount of iron. Zinc is a necessary cofactor in hundreds of enzymes and also in a large number of transcription factors. It is needed for synthesis of DNA, RNA and protein molecules and is, therefore, needed for all growth processes both at the cellular and organism level, as well as being very important for immunological functions and resistance against infectious diseases [5,27]. Zinc deficiency is one of the common causes of impaired growth (stunting) in children. In severe cases it can lead to dwarfism [27]. Zinc deficiency in pregnant women can lead to foetal damage (all degrees from very mild to severe) [27].

It may be concluded that a diet deficient in animal foods will easily lead to a number of deficiency conditions that are associated with growth and developmental disturbances in foetuses and children, enhanced mortality for women during childbirth and enhanced mortality because of infectious diseases both among children and adults.

Soil depletion of mineral nutrients can lead to micronutrient and macronutrient deficiencies also in the human population

Dietary deficiencies can also occur as a consequence of depletion of certain mineral nutrients in the soil [25,34,35]. This may happen:

(i) As a consequence of prolonged chemical weathering under humid conditions (for example for zinc and copper) [35].
(ii) Because of low rates of atmospheric deposition in the inland (in the case of iodine, selenium and sulphur) [36].
(iii) Because of deforestation and enhanced soil erosion causing loss of several plant-biophile nutrient elements including iodine, sulphur, selenium and zinc [37].
(iv) Because of loss by frequent anthropogenic fires (especially for sulphur and selenium) [38].

Sulphur deficiency in the soil can limit total protein production in the plants in a similar way as nitrogen deficiency does [33,34]. But the inhibitory effect is strongest for those plant proteins that contain much sulphur amino acids [34]. Sulphur deficiency in the soil can, therefore, lead to a qualitative change in the composition of cereal proteins, with reduction of the concentrations of sulphur amino acids [34].

There is reason to expect that all of the soil-depleting factors mentioned here must be important in parts of Tanzania, and also in most other countries in the region. They will, however, not be equally important in all parts of the country. What can be safely inferred is, nevertheless, that there frequently will be a synergistic interaction between more easily observable causes of malnutrition (too monotonous diets often as a consequence of poverty) and more hidden causes being a consequence of depletion of the nutrient element concerned in the soil. Taking zinc as an example, it is probable that zinc deficiency often could arise as a consequence of the interaction of:

(i) Zinc deficiency in the soil due to a combination of extensive chemical weathering, deforestation and accelerated soil erosion.
(ii) High consumption of phytate.
(iii) Low consumption of animal foods (most often as a result of poverty).

Returning now to the figures found in Table 2, it may be reasonable to explain the high prevalence of iron deficiency anaemia in Tanzania as due to a combination of not very high intakes and poor bioavailability, with the last factor being the most important. Some of the same factors that can explain why iron deficiency is so common (especially a low proportion of iron-rich animal foods to phytate in the overall diet) will also affect the intestinal absorption of zinc. It is possible that zinc deficiency, similarly as iron deficiency, may be very prevalent in Tanzania, partly as a consequence of poor intestinal absorption and partly as a consequence of zinc-depleted soils causing reduction of the zinc concentration both in maize and other plant protein foods. Zinc deficiency has been reported to be widespread in Malawi [39]. It may be possible that this observation might be valid for many of those parts of sub-Saharan Africa where maize is the dominant staple food.

Role of whole fish products as sources of vitamin B_{12}, selenium, iron, zinc, calcium and nucleic acids

Fish products have traditionally been an important part of the diet in several counties in Africa and Asia not only as sources of high-quality dietary protein, but also as sources of calcium and several micronutrients, including iodine, selenium, vitamin B_{12}, niacin, iron and zinc. This is because it has been common to eat products made from whole fish (often in the form of dried products made from small species). Such products must have been used for thousands of years.

Most of the calcium content in the fish organism is found in the skeleton and some of it in the skin (in the scales), while the skeletal muscle contains practically no calcium [19]. Myoglobin-poor fish fillet (for example cod fillet) also contains very little iron and zinc, even though it is a good source for selenium and iodine [19]. Zinc, however, is found in the fish bones, and the visceral fraction is an excellent source both of zinc and iron [40]. Much of the iron content of fish viscera is also in the form of heme-iron (in the gills, heart and large blood vessels), which is much better absorbed in humans compared to non-heme-iron [28]. Products made from whole fish are exceptionally good sources of vitamin B_{12}, and most likely also good sources of vitamin K. They are also good sources of lipid components such as long-chain polyunsaturated fatty acids and choline, and of conditionally essential nutrients such as nucleotides, taurine and carnitine.

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In the industrial countries of Europe and North America, it is much more common, however, to eat the fish muscle (the fillet) alone, while discarding the head, the skeleton and the visceral fraction (sometimes with exception of the roe and the liver, *e.g.* from cod). From a nutritional point of view, the difference between fish fillet and products based on whole fish can be considered as completely analogous to the difference between refined and unrefined cereal products. The consumption of refined cereal products has become very common in many countries mainly as a consequence of cultural changes that took place because of the industrial revolution and colonial trade. The preference of fish fillet over whole fish products may be related to the abundance of large species of fish such as cod in the North Atlantic (with big fishes being preferred over the small ones), while the traditional use of whole dried fish in many countries in Asia and Africa may be related to the larger relative importance of small species of fish in many of those countries. The preference either for products made from whole fish or fish fillet in different parts of the world may thus have much deeper roots in historical tradition than the use of refined cereal foods (such as polished rice, white wheat flour and refined maize flour), which is a comparatively recent phenomenon. However, Henry A. Schroeder's slogan "Pure food is poor food" is valid in both cases [41].

Maize and products made from whole fish have compositions that may be regarded as complementary to each other. Whole-fish products are good to excellent sources of many of those nutrients that will be deficient in too monotonous maize-based diets, and maize is a good source of some of those nutrients that will be deficient (such as copper and manganese) if one should live only on fish. A combination of unrefined white maize and whole fish can, however, not alone cover the requirement for vitamins C, A and E. Supplements of vegetables, fruit, unrefined palm oil and other oils will provide these vitamins, and will also help to increase the intakes of vitamin K, folate, boron, potassium, manganese, magnesium, xanthophylls and flavonoids (or other polyphenolic plant antioxidants).

Some of the nutrients found in whole fish are especially important for pregnant and lactating women. They are also important to small children because they are important for normal growth and development, especially the development of the skeleton (zinc, calcium) and the central nervous system (iodine, zinc, iron, vitamin B_{12}, long-chain *omega*-3 PUFAs and choline). Whole fish is also an excellent source of several nutrients. These nutrients are important for immunological functions, for the integrity of the intestinal mucosa and for protecting host tissues against oxidative and nitrosative stress associated with infections which is all important for bringing down the death rate among small children because of common infections such as diarrheal diseases, lower respiratory infections and measles, and most likely for highly virulent forms of influenza [6].

Traditional fisheries and traditional methods of fish preservation are now threatened both by the problem of over-exploitation of fish resources and by modernization processes. This may lead to the substitution of more refined and nutritionally less valuable fish products instead of the traditional unrefined products (fillet products

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instead of whole fish) and may also cause the diversion for animal feed production of fish that was formerly used for human consumption.

Industrial fish resources from outside the coasts of Africa should be used for production of food-grade products rather than for production of animal feeds, which is what is happening today. From a technological point of view, it is entirely feasible to make high-quality products from industrial fish, which from a nutritional point of view have precisely the same advantages as traditional products such as dried kapenta. It should be noted that production costs for FPC type B depend strongly not only on the price of the raw material, but also on the scale of production. It will be considerably cheaper to produce and sell large amounts than small amounts of otherwise similar products. It is imperative, though, that such industrial products must be hygienically safe, that they must be stored and packed under inert gas so as to avoid rancidification and that they must contain no toxic additives such as ethoxyquin or other mutagenic antioxidants. The problem of storage stability must be solved either using package under inert gas or natural antioxidants that are completely non-toxic.

CONCLUSION

Dried whole small fish such as kapenta and fish flour have nutrient compositions that are complementary to the maize flour, and a relatively small supplement of these fish products will be excellent sources of several nutrients deficient, poorly available or totally lacking in the maize flour. The requirements of vitamins A, C and E have to be met through other sources such as vegetables and unrefined palm oil.

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We are grateful to Lisbeth Eriksen at The library of The Norwegian University of Life Sciences for helping with search for tables and data, as well as to the late Cato Aall, who was one of the main pioneers in the Norwegian FPC project during the 1970s (with the double aim of combating serious global health problems and enhancing the utilisation of industrial fish resources for human consumption rather than as animal feed), and also was one of the initiators of the current investigation. Cato Aall, who died in July 2008 on his 79th birthday, was as a young man (and student political activist) a staunch supporter of political freedom movements in Africa, including Zambia (or North Rhodesia, as it then was called). After having spent several years in Africa, he became heavily involved in the efforts then led by Norwegian health authorities (the National Nutrition Council/Norwegian FAO Committee) to promote the use of FPC type B as a cost-effective method to prevent protein-energy malnutrition, as well as for alleviating several other health problems in the developing countries of Africa and Asia. Cato spent his last years in Africa in an effort to bring medical assistance to AIDS patients and especially for trying to alleviate malnutrition among HIV patients in Africa.

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Table 1:Concentrations of some nutrients in kapenta and Norwegian fish powder

Nutrient	Kapenta	Fish powder	Unit
Water	6.5	4.8	%
Protein	72.9	72.8	%
Cysteine	7.5	8.2	g/kg
Methionine	21.3	20.7	g/kg
Aspartic acid	63.2	69.2	g/kg
Threonine	27.8	27.5	g/kg
Serine	27	28.8	g/kg
Glutamic acid	93.8	102.9	g/kg
Proline	24.5	31	g/kg
Glycine	40.7	45.9	g/kg
Alanine	42.8	46	g/kg
Valine	37.1	38.4	g/kg
Isoleucine	30.3	34.5	g/kg
Leucine	51.1	54.1	g/kg
Tyrosine	22.6	24.4	g/kg
Phenylalanine	28	30.7	g/kg
Histidine	26.6	17.4	g/kg
Ornithine	0.4	<0.1	g/kg
Lysine	55.9	58.8	g/kg
Arginine	40.3	43.9	g/kg
Hydroxyproline	<0.1	<0.1	g/kg
Tryptophan	8.15	8.31	g/kg
Taurine (free)	6.72	5.85	g/kg
Iron	72	77	mg/kg
Vitamin B_{12}	280	360	ug/kg

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Table 2: Energy content and concentration of nutrients in 100 g maize flour[a], dietary guidelines advisory for children 1-3 years old[b] and nutrient contribution of 100 g maize flour to children 1-3 years

Parameter	Nutrients in 100 gram white maize flour	Dietary Guideline for child 1-3 years	% of advised intake from 100 g white maize flour
Energy, kcal	361	1000	31
Vitamin A , ug	3	300	1
Vitamin E, mg	0.4	6.0	7
Vitamin K, ug	0.3	30	1
Vitamin C, mg	0.0	15	0
Thiamin, mg	0.2	0.5	49
Riboflavin, mg	0.1	0.5	16
Niacin, mg	1.9	6.0	32
Pantothenic acid, mg	0.7	2.0	33
Vitamin B_6, mg	0.4	0.5	74
Vitamin B_{12}, ug	0.0	0.9	0
Folate, ug	25	150	17
Calcium, mg	7	500	1
Potassium, mg	315	3000	11
Phosporus, mg	272	460	59
Magnesium, mg	93	80	116
Iron, mg	2.4	7	34
Zinc, mg	1.7	3	58
Copper, mg	0.2	0.3	68
Manganese, mg	0.5	1.2	38
ILE, mg	248	315[c]	79
LEU, mg	850	693 [c]	123
LYS, mg	195	643 [c]	30
MET+CYS, mg	270	315 [c]	86
PHE+TYR, mg	622	592 [c]	105
THR, mg	261	340 [c]	77
TRP, mg	49	88 [c]	56
VAL, mg	351	403 [c]	87
HIS, mg	211	227 [c]	93

[a] Whole grain, white, USDA food table [21]
[b] Dietary Guidelines for Americans 2005 [22]
[c] RDA, children, 2 years 12 kg [42].

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Table 3: The composition of some amino acids, vitamins and minerals in 100 grams kapenta, fish powder and maize flour, and the estimated daily requirement of these nutrients in a 2 year old child (weighing 12 kg)

	Kapenta	Fish powder	Corn flour whole grain, white	Estimated requirement in children 2 years (12 kg) b
Water g	6.5	4.8	10.9	
Protein g	72.9	72.8	6.9	12.6 g/day
Aminoacids:				
Cysteine g/100g	0.75	0.82	0.13	
Methionine g/100g	2.13	2.07	0.15	0.32 (met+cys) g/day
Aspartate g/100g	6.32	6.82	0.48	
Threonine g/100g	2.78	2.75	0.26	0.34 g/day
Serine g/100g	2.70	2.88	0.33	
Glutamine g/100g	9.38	10.29	1.30	
Proline g/100g	2.45	3.10	0.61	
Glycine g/100g	4.07	4.59	0.28	
Alanine g/100g	4.28	4.66	0.52	
Valine g/100g	3.71	3.84	0.35	0.40 g/day
Isoleucine g/100g	3.03	3.45	0.25	0.32 g/day
Leucine g/100g	5.11	5.41	0.85	0.69 g/day
Tyrosine g/100g	2.26	2.44	0.28	
Phenylalanine g/100g	2.80	3.07	0.34	0.59 (phe+tyr) g/day
Histidine g/100g	2.66	1.74	0.21	227 g/day
Ornithine g/100g	0.04	<0.01		
Lysine g/100g	5.59	5.88	0.20	0.64 g/day
Arginine g/100g	4.03	4.39	0.35	
Hydroxyproline	<0.01	<0.01		
Tryptophan g/100g	0.82	0.83	0.05	0.09 g/day
Taurine g/100g	0.67	0.59		
Minerals and vitamins:				
Iron mg	7.2	7.2	2.38	7 mg/day
Zinc mg		6.0 c	1.73	3 mg/day
Iodine ug		300 c		90 ug/day
Selenium ug		200 c	15.4	20 ug/day
Calcium mg		3000 c	7	500 mg/d
Phosphorus mg		2000 c	272	460 mg /d
Potassium mg		1300 c	315	1800 mg/d e
Magnesium mg		220 c	93	1.2 mg /d
Vitamin B_{12} ug	28	36	0.00	0.9 ug/day

[a] USDA National Nutrient Database for Standard Reference[21].

[b] RDA, children, 2 years 12 kg [42].

[c] Reported by the producer of the fish powder product.

[e] Dietary Guidelines 2005 [22].

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Table 4: Protein, and mineral nutrients (nitrogen, calcium, phosphorus, magnesium, iron, iodine, selenium, zinc and fluoride in fishmeal, skimmed milk, cow beef, pork, cod and salmon

	Fish meal average (a)	Skimmed milk powder (b)	Cow beef chuck boneless (b)	Pork butt, boneless and skin-less (b)	Cod, frozen (b)	Sal-mon (b)
Protein g/kg	716	353 (c)	176 (c)	151 (c)	158 (c)	202(c)
N g/kg	114 (d)	56	28	24	25	32
Ca g/kg	18	14	0.15	0.06	0.16	0.16
P g/kg	17	9.8	1.5	1.2	1.6	2.4
Mg g/kg	1.3	1.3	0.18	0.12	0.17	0.25
Fe mg/kg	269	4.5	24	7.6	1.8	4.0
I mg/kg	2.8	(e)	-	-	-	-
Se mg/kg	2.8	0.02	0.02	0.06	0.23	0.26
Zn mg/kg	113	47	63	21	2.8	4.3
F mg/kg	100	- (f)	0.2	<0.2	0.2	0.3

a) Average for Norwegian fish meals produced from several different species of fish, mainly data from Opstvedt et al [20] The iron concentration given is probably much too high compared with FPC produced today (because of much less contamination iron in modern factories).
b) From: Koivistoinen [19].
c) N concentration multiplied by a factor of 6.3
d) Protein concentration divided by a factor of 6.3.
e) Not given in the tables of Koivistoinen [19].
f) Not determined.

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Table 5: Quantity (g per day) of various animal foods needed to cover the entire recommended dietary allowance for a child 1-3 years old* for calcium (Ca), phosphorus (P), magnesium (Mg), iron (Fe), zinc (Zn), iodine (I) and selenium (Se)

	Fish meal	Skimmed milk powder	Cow beef	Pork meat	Frozen cod fillet	Salmon
Ca	28	35	3333	8929	3125	3125
P	27	48	307	383	288	191
Mg	62	62	440	670	470	320
Fe	26	1500	290	920	3900	1750
Zn	26	63	47	143	1070	700
I	30	-	-	-	-	-
Se	7.1	1000	1000	330	87	77

*Calculated from figures in Table 2 and Dietary Guidelines, 2005 [22].

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