Improving Young Child Feeding in Eastern and Southern Africa

Household-Level Food Technology

Proceedings of a workshop held in Nairobi, Kenya, 12-16 October 1987
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Editors: D. Alnwick, S. Moses, and O.G. Schmidt

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Abstract

The weaning period, that is the period in a young child's life when supplementary foods are introduced to complement breast milk, poses great nutritional risk to children in developing countries. By the end of the second year of life, one-third of children in eastern and southern Africa are chronically malnourished. The following factors contribute to the growth faltering commonly observed in weaning-age children: low nutrient intake, high incidence of diarrheal disease (often caused by contaminated weaning foods), and recent declines in duration and intensity of breastfeeding.

Food scientists, nutritionists, and health planners working in Africa and South Asia met in an international workshop to examine household-level food technologies that hold promise for improving nutrition of infants and young children. After reviewing current knowledge of breastfeeding and weaning practices in eastern and southern Africa, participants discussed the use in weaning diets of fermented foods and germinated flour, for both improved nutrient intake by young children and decreased risk of food contamination. Research that should be conducted into the effectiveness of the food technology was identified and its diffusion at the community level discussed.

This publication contains the proceedings, conclusions, and recommendations of the workshop. It is directed at scientists and health planners who are involved in nutrition research and developing programs to improve feeding of infants and young children in developing countries.

Résumé

Le sevrage, c'est-à-dire la période où l'on commence à donner des aliments solides à un jeune enfant en complément du lait maternel, présente de graves risques nutritionnels pour les enfants dans les pays en développement. Dès la fin de leur deuxième année, le tiers des enfants en Afrique orientale et australe souffrent de malnutrition chronique. Les facteurs suivants sont à l'origine du retard de croissance que l'on retrouve couramment chez les enfants en âge d'être sevrés : carence nutritionnelle, forte prévalence des maladies diarrhéiques (qui s'expliquent souvent par la contamination des aliments) et diminution récente de la durée et de l'intensité de l'allaitement maternel.

Des spécialistes des sciences de l'alimentation, des nutritionnistes et des planificateurs de la santé travaillant en Afrique et en Asie du Sud se sont réunis dans le cadre d'un atelier international afin d'examiner des technologies alimentaires applicables au niveau des ménages qui semblent prometteuses pour améliorer la nutrition des nourrissons et des jeunes enfants. Après avoir examiné les connaissances actuelles en matière d'allaitement au sein et les pratiques de sevrage en Afrique orientale et australe, les participants ont discuté de l'utilisation, au cours du sevrage, d'aliments fermentés et de farine germée, tant pour améliorer l'apport nutritionnel chez les jeunes enfants que pour diminuer les risques de contamination des aliments. Ils ont également discuté des recherches qu'il y aurait lieu d'entreprendre sur l'efficacité des technologies alimentaires et sur leur diffusion dans la collectivité.
Cette publication fait un compte rendu des discussions de l'atelier et présente ses conclusions et ses recommandations. Elle s'adresse aux scientifiques et aux planificateurs de la santé qui participent à des recherches en matière de nutrition et à l'élaboration de programmes visant à améliorer l'alimentation des nourrissons et des jeunes enfants dans les pays en développement.

Resumen

El período de destete, es decir, aquel período en la vida de un niño en que se introducen en su dieta alimentos suplementarios para complementar la leche materna, representa un gran riesgo nutricional para los niños de países en vías de desarrollo. Hacia el final de su segundo año de vida, un tercio de los niños en África oriental y del sur muestran signos de malnutrición crónica. Los siguientes factores contribuyen al crecimiento vacilante que se observa comúnmente en los niños que se encuentran en edad de dejar la lactancia materna: baja ingestión de nutrientes, alta incidencia de diarrea (a menudo causada por alimentos para el destete contaminados), y nuevas disminuciones en la duración e intensidad de la alimentación proveniente del pecho de la madre.

Científicos del campo de los alimentos, especialistas en nutrición y planificadores de la salud que trabajan en África y en el Sur de Asia se reunieron en un taller internacional para examinar las tecnologías de alimentos que se utilizan en el hogar y que prometen buenos resultados en el mejoramiento de la nutrición de lactantes y niños pequeños. Después de analizar el conocimiento que existe actualmente sobre la alimentación recibida a través del pecho de la madre y las prácticas que se utilizan para el destete en el oriente y sur de África, los participantes discutieron el uso en dietas para el destete de alimentos fermentados y harina germinada para que los niños puedan ingerir nutrientes mejorados y haya una disminución en el riesgo causado por la contaminación de los alimentos. Se identificó la investigación que se debe realizar sobre la efectividad de las tecnologías de alimentos y se discutió su difusión en el seno de la comunidad.

Esta publicación contiene las actas, conclusiones y recomendaciones del taller. Está dirigida a científicos y planificadores de la salud que participan en la investigación nutricional y en programas de desarrollo para mejorar la alimentación de lactantes y niños en los países en desarrollo.
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IMPROVED IRON AVAILABILITY IN WEANING FOODS THROUGH THE USE OF GERMINATION AND FERMENTATION

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Abstract: Anemia is second only to malnutrition as the most common health problem in Tanzania and in most developing countries. Although malaria is an important causative factor, it seems that iron deficiency anemia is the most common type of anemia in Tanzania. Despite clear indications of its prevalence, however, most dietary surveys have concluded that iron intake in general is adequate. It seems clear, therefore, that the factor of greatest nutritional significance is the bioavailability of the food iron. The staple foods of Tanzania contain factors such as phytic acid and tannins, that strongly inhibit the bioavailability of iron. By using traditional household technologies such as germination and fermentation, as well as soaking, the effect of these inhibitors could be reduced. To measure the iron availability of weaning diets, we developed a rapid and simple in vitro technique; this technique, while providing results that are comparable to those from human studies, is less laborious and costly. We measured the amount of available iron in various staple foods that had been processed by germination or fermentation. We found that both processes, when combined with a modified preparation and cooking procedure, could increase the amount of available iron to 2-6 times that of untreated staple food. The processes involve activation of enzymes that significantly reduce the amount of phytic acid in the foods and thus increase iron availability. The paper emphasizes the significance of this discovery for the development of a practical, household-level approach to the reduction of anemia.

Anemia is second only to malnutrition as the most common health problem in Tanzania and in most developing countries. For practical purposes, anemia is regarded as that condition in which a hemoglobin concentration exists that is lower than an arbitrarily selected value; it is recognized, however, that because of the overlap between normal

1 The studies were carried out in collaboration with the Tanzania Food and Nutrition Centre and funded by the Swedish Agency for Research Cooperation with Developing Countries.
and anemic values in a population, such a distinction is a matter of probability. The widely accepted cutoff levels are 130 g/L for men, 120 g/L for women, and 110 g/L for pregnant women and young children (WHO 1968). More severe anemia with microcytosis and hypochromia is indicative of advanced iron deficiency.

Before summarizing the situation with regard to anemia in Tanzania, I will give a general picture of the relative frequency with which different types of anemia appear. The majority of anemias are hypoproliferative, with inflammation, iron deficiency, and acute bleeding being the most common disorders (Hillman and Finch 1985).

The anemia problem in Tanzania has, on the whole, been a concern of general nutritional surveys. The screening test in all these surveys has involved a measurement of the hemoglobin level. The use of a low hemoglobin value as a diagnosis of anemia does not, however, discriminate among possible causes for the anemia. Acute and chronic infection can cause an immediate and significant decrease of the Hb value; this latter, however, is seen only at a late stage in iron deficiency, when iron stores are exhausted. The relative insensitivity of the hemoglobin measurement is also attributable to the wide scatter of values in normal subjects.

Surveys in Tanzania have therefore attempted to elucidate some of the underlying causes of anemia. Data from the nutritional surveys of Tanzania indicate a wide incidence of anemia (Table 1): in some villages, up to 39% of the young children were found to be anemic. In some regions, a significant relationship was found between anemia and malaria, hookworm, and schistosomiasis infections. The effect of minor infections was not, however, investigated; as was mentioned earlier, the prevalence of a real iron-deficiency condition cannot be established with the Hb method.

Sequential changes in the development of iron deficiency are shown by the use of other parameters. From a clinical standpoint, a decrease in storage iron is recognized by a reduction in serum ferritin concentration or by a decrease in stainable iron in the bone marrow, or both. When iron stores are exhausted and a negative iron balance continues, there is a reduction in the supply of iron to the erythroid marrow. This is reflected by a decrease in the saturation of the plasma iron transport protein, transferrin. As a result, hemoglobin synthesis becomes impaired, and there is a rise in red cell protoporphyrin concentration. The restrictions in hemoglobin production eventually lead to a fall in hemoglobin concentration below the cutoff level for the individual.

For a complete picture of an iron deficiency situation, therefore, one must rely on analytical methods that measure the size of the iron stores. In a recent study from the Pawaga division in Tanzania, the protoporphyrin level was measured: about 50% of the children under 5 years of age (n = 651) showed values that indicated an iron deficiency state; more than 90% had an Hb value below the cutoff level, indicating anemia. Indirect evidence also proves iron deficiency to be a major cause of anemia in developing countries: inspection of the data on dietary iron absorption provides strong support for such a conclusion.
Table 1. Anemia by area and population group (from nutrition surveys in Tanzania).

<table>
<thead>
<tr>
<th>Date</th>
<th>Area</th>
<th>Type of population surveyed</th>
<th>Sample size</th>
<th>Mean Hb</th>
<th>Prevalence of anemia (%)</th>
<th>Hb g% cutoff point</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972</td>
<td>Dar</td>
<td>Pregnant women</td>
<td>1317</td>
<td>9.3</td>
<td>100</td>
<td>11</td>
</tr>
<tr>
<td>1973</td>
<td>Kilosa</td>
<td>Women all ages</td>
<td>1702</td>
<td>11.2</td>
<td>28</td>
<td>10</td>
</tr>
<tr>
<td>1973</td>
<td>Bagamoyo</td>
<td>Women all ages</td>
<td>1467</td>
<td>10.4</td>
<td>15</td>
<td>11.5</td>
</tr>
<tr>
<td>1974</td>
<td>Morogoro</td>
<td>Village 0-4 years</td>
<td>31</td>
<td>10.8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1974</td>
<td>Mbeya</td>
<td>Village 0-4 years</td>
<td>60</td>
<td>11.7</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1974</td>
<td>Tabora</td>
<td>Village adults</td>
<td>328</td>
<td>12.8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1974</td>
<td>Morogoro</td>
<td>Village adults</td>
<td>323</td>
<td>12.4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1974</td>
<td>Mbeya</td>
<td>Village adults</td>
<td>336</td>
<td>13.6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1974</td>
<td>Tabora Morogoro Mbeya</td>
<td>Village adult females</td>
<td>516</td>
<td>12.2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1979</td>
<td>Rufiji</td>
<td>Village under 5s</td>
<td>288</td>
<td>7.9</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1979/80</td>
<td>Iringa</td>
<td>Village under 5s</td>
<td>1143</td>
<td>11.2</td>
<td>15.9 (0-39)</td>
<td>10</td>
</tr>
<tr>
<td>1984</td>
<td>Iringa</td>
<td>Village under 5s</td>
<td>979</td>
<td>11.8</td>
<td>25</td>
<td>10</td>
</tr>
<tr>
<td>1984</td>
<td>Iringa</td>
<td>Village under 5s</td>
<td>200</td>
<td>-</td>
<td>25</td>
<td>10</td>
</tr>
</tbody>
</table>

Nature of Dietary Iron

Our knowledge of food-iron absorption has expanded greatly during the last 10 years, and stems particularly from the development of isotopic methods to measure iron absorption from complete meals (Cook et al. 1972; Hallberg and Bjorn-Rasmussen 1972; Layrisse and Martinez-Torres 1972). It is now known that because of separate pathways of entry into the intestinal mucosal cell, dietary iron may be composed
of two distinct pools: a pool of hem iron and one of nonhem iron. Hem, providing up to 10-15% of food iron consumed in industrialized countries, consists of the hemoglobin and myoglobin in animal foods. Hem iron is 20-30% absorbed and may account for as much as one-fourth of the iron absorbed from high meat diets. Because hem-iron absorption is little affected by the nature of the meal and only slightly influenced by the iron status of the individual, its contribution can be approximated by chemical measurement of its content in the diet, assuming an absorption of 25%.

Nonhem iron is contained in cereals, pulses, fruits, vegetables, and dairy products; it constitutes the major and, in developing countries, frequently the only source of dietary iron. The absorption of this nonhem iron is highly variable and depends on the nature of the meal. In any given meal containing a combination of foods, a common pool of nonhem iron is formed in the intestinal lumen. The absorption from this pool is determined by the composite effect of factors promoting or impairing iron availability. Factors known to stimulate absorption of nonhem iron are meat, poultry, seafood, and various organic acids, particularly ascorbic acid. A large number of substances are known to impair the absorption of iron: these include polyphenols such as tannins, phytates (Gillooly et al. 1983), certain forms of protein (INACG 1982), and some fibres. Foods that have a strong inhibitory effect on iron absorption therefore include tea, coffee, egg yolk, and bran. Depending on the content of the enhancing and inhibiting substances, absorption of iron from a meal may range from 1 to 40% in individuals with comparable iron status.

Despite the wealth of information available on factors affecting iron absorption from single meals, the information is limited as to absorption from a complete diet. Typical meals in different regions of the world (Hallberg et al. 1983; Narasinga Rao et al. 1983; Acosta et al. 1984) can be separated into three broad categories: low, intermediate, and high bioavailability, with average absorption both from the hem and from the nonhem iron of about 5, 10, and 15%, respectively; this is applicable to an individual with no iron stores but with normal iron transport. There are some diets beyond both extremes of the 5-15% bioavailability range. Iron absorption from diets consisting almost entirely of cereals may therefore be as low as 1-2%; in diets containing large quantities of meat, fish, or poultry, however, absorption may approach 20-25%.

To conclude, all our information indicates that the iron content of cereal-based diets is usually adequate. One should also mention contamination of iron that may contribute up to several times the amount of indigenous iron in the diet; the availability of this is, however, more or less unknown. The availability of the intrinsic iron can vary considerably, from 1 to 40%.

What then are the realistic and practical means of reducing iron deficiency anaemia in developing countries? One could consider the following three strategies: the distribution of iron tablets to vulnerable groups, such as young children and pregnant and lactating mothers; the fortification of certain staple foods with iron; and an increase in the bioavailability of the food iron. The first strategy implies an extended and well-functioning MCH system, and the second, a centrally distributed staple food. In many countries, neither of these prerequisites exists. We are left, therefore, with
the third strategy: to improve the iron availability of cereal diets. In our collaborative research program with TFNC, we have carried out studies on methods of diminishing the inhibitory effects of phytates and tannins on the iron availability of cereal foods through the use of traditional household techniques such as germination and fermentation.

Germination and Fermentation: Effect on Phytic Acid and Iron Availability

Phytic acid (chemically, inositol-hexa-phosphate) has a strong ability to complex mineral irons such as Fe$^{2+}$ and Fe$^{3+}$, Zn$^{2+}$, Mg$^{2+}$, and Ca$^{2+}$. These mineral - phytic acid complexes are usually of low solubility and will, therefore, make the minerals unavailable for absorption. In the cereal seed, the phytic acid is distributed mainly in the aleurone layer (Lott and Ockendenen 1986); dehulling the seeds will, therefore, significantly reduce the amount of phytic acids (up to 50-60%). The amounts remaining will, however, still affect the iron availability.

Another way of decreasing the amount of phytic acid in the seed is to activate the phytases that are available in small amounts in nearly all cereal varieties (Nayini and Markakis 1986). The phytic acid is then hydrolyzed into lower inositol-phosphates (penta- to

Fig. 1. Relative inositol-phosphate content in soaked (12 h) sorghum samples. ---, ungerminated whole flour; ----, germinated whole flour. IP$_3$ to IP$_6$ = inositol containing 3 to 6 phosphates per inositol residue.
mono-phosphates); as measured in in vitro systems, however, only the hexa- and penta-inositol-phosphates form insoluble complexes with iron. Germination of cereal seeds is also known to increase the phytase activity. We used a new method to measure the inositol-phosphates by extracting in dilute HCl and quantifying using ion-pair chromatography and HPLC (Sandberg and Adherinne 1986). In white sorghum that had been germinated for 48 h, the amounts of hexa-inositol-phosphates (IP6) and penta-inositol-phosphates (IP5) are significantly lower than in the ungerminated flour. We further activated the phytases of the sorghum samples by soaking them in water for 12 h and adjusting the pH in the soaking water to 5.0 by the adding HCl. Figure 1 shows that soaking at optimal pH conditions for the phytases reduces the amounts of IP6 and IP5 in the germinated sorghum flour to less than 5% of that in the ungerminated whole flour.

Our next step was to subject the samples to a natural, lactic acid bacterial fermentation. The flours were soaked in water and left at room temperature for 2-3 days; the lactic acid produced in the fermented slurry reduced the pH from an initial value of 6 to about 4. The amount of phytic acid (IP6 + IP5) is reduced even more in these fermented samples, and the germinated flour has no detectable amounts of IP6 and IP5. Table 2 shows a summary of the amounts of IP6 and IP5 in µmol/g in the samples studied.

What is the effect of these treatments on iron availability? The iron availability was estimated using an in vitro method developed at our department in Gothenburg (Svanberg et al. 1988). The food sample is progressively digested using a three-enzyme system. The amount of solubilized iron is detected in an atomic absorption spectrophotometer. The relationship between the percentage of solubilized iron and the iron availability measured in human studies using the radiotag method (Hallberg and Bjorn-Rasmussen 1972) shows a high correlation (r = 0.99, p ≤ 0.001), on 16 different foods with and without animal proteins.

The different sorghum samples in this study were analyzed for soluble iron using this in vitro method. Figure 2 shows the relationship between soluble iron and phytic acid content. The lactic acid fermentation doubles the amount of soluble iron using dehulled flour, and increases it six times using germinated flour.

Table 2. Amount of IP6 + IP5 (µmol/g) in different sorghum samples; the effects of dehulling, germination, soaking, and fermentation.

<table>
<thead>
<tr>
<th>Sorghum (white)</th>
<th>Untreated</th>
<th>Soaked (12 h, pH = 6)</th>
<th>Fermented (48 h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nongerminated</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whole flour</td>
<td>5.45</td>
<td>2.70</td>
<td>0.20</td>
</tr>
<tr>
<td>85% extracted</td>
<td>5.20</td>
<td>2.20</td>
<td>0.40</td>
</tr>
<tr>
<td>Germinated</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whole flour</td>
<td>3.50</td>
<td>0.40</td>
<td>n.d.a</td>
</tr>
</tbody>
</table>

aNot detectable.
Fig. 2. Soluble iron and phytic acid content in different sorghum samples.

To conclude, traditional, household-level food methods, such as soaking, germination, and fermentation, have been shown under laboratory conditions to reduce significantly the phytic-acid content in white sorghum. The iron solubility, and therefore the iron availability, were increased, depending on the treatment, 2-6 times. In quantitative terms, this means that a diet of "low bioavailability" has been changed into one of "intermediate to high bioavailability"; this could otherwise be achieved only by the inclusion of generous quantities of meat, or of foods containing high amounts of ascorbic acid.

References


