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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

Proceedings



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Improving Young Child Feeding in Eastern and Southern Africa

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Editors: D. Alnwick, S. Moses,
and O.G. Schmidt



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PROGRESSIVE
HOUSEHOLD
TECHNOLOGY

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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 señales 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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FORMULATION AND MICROBIOLOGICAL SAFETY OF CEREAL-BASED WEANING FOODS

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Abstract The appropriateness of a composite weaning food can be determined by a consideration of the following factors: the target group - its energy and protein requirements, and its daily food intake capacity; the use and chemical composition of locally produced ingredients; and the acceptability of the food, in terms of palatability and consistency. Examples are given for the calculation of mixtures of white sorghum flour, pigeon pea meal, and groundnut meal, with vegetable oil or sorghum malt added to adjust the viscosity. This paper presents the microbiological properties of sorghum porridge and of sorghum composite mixtures. In particular, it examines the effect of controlled lactic fermentation on the microbiological stability of the final cooked products. Controlled lactic fermentation of a sorghum base achieved pH 3.80 after 12 h at 30°C, and yielded porridges in which added Salmonella typhimurium was destroyed during storage experiments at 30°C for 24 h. Similar effects could be obtained in sorghum composite mixes with pigeon pea and groundnut meals. It is concluded that lactic fermentation has the potential to be an excellent protective treatment for cereal-based composite foods.

It has recently been estimated by the United Nations Children's Fund that over 14 million infants and children under 5 years of age die annually in the tropical regions of the world (UNICEF 1987). One of the major causes is a watery diarrhea - the result of infection by pathogenic microorganisms. Although other infections such as Ascaris roundworm are also regarded as detrimental to nutritional status (Stephenson et al. 1980), the occurrence of acute watery diarrhea is a major cause of dehydration and of poor absorption of nutrients from the diet (NRC 1985); this is estimated to cause an annual mortality of 5 million infants and children (Evans 1986). We must also include the inadequate intake of macronutrients and of energy that results in

protein energy malnutrition (PEM), with an estimated mortality of 3 million per year (Evans 1986).

Microorganisms associated with diarrheal diseases are found particularly in three families of bacteria: the Enterobacteriaceae, among which the genera Escherichia, Salmonella, Shigella, and Yersinia are well known as causative agents of food-borne gastroenteritis; the Vibrionaceae, associated with the cholera diseases, and the Spirillaceae, among which the genus Campylobacter is increasingly regarded as a potential food infection-causing bacterium. Although any human risks contracting a food-borne infection from the consumption of contaminated food or water, epidemiological evidence shows that the people particularly at risk are those who are weak or in a poor nutritional condition (Chen 1983). Such persons are mainly infants, young children, the sick, and the elderly. In the fight against malnutrition, we should therefore focus on a combination of improved intake of essential nutrients and protection against potentially harmful microorganisms.

In this paper, we attempt to deal with both aspects from the perspective of infant and young child feeding, particularly during the weaning period. The concept of cereal-based composite weaning foods will be discussed. This is a matter of particular interest at the Department of Human Nutrition of the Agricultural University, Wageningen, The Netherlands, and at the International Courses in Food Science and Nutrition of the International Agricultural Centre, Wageningen, The Netherlands, where the concept has been tested by the practical work of several project groups of foreign course participants. The microbiological properties of cereal-based composite mixes will then be discussed, giving an idea of some of the research taking place at the Department of Food Science of the Agricultural University. Recently, Alnwick (1986) emphasized the need for data on the preservation by fermentation of sorghum- and other cereal-based porridges. The aim of this paper is to provide an insight into the effect of lactic fermentation on the microbiological safety of such products.

Weaning Foods in Africa

Cereal-based porridges ("oji," "ogi," etc.) are commonly used as weaning foods. There are three possible ways of preparing these porridges: (a) fresh flour + water → boil → consume ("sweet" porridge); (b) fresh flour + water → ferment overnight → boil → consume (sour porridge); and (c) fresh flour + water → boil → ferment → consume (sour porridge). Systems (a) and (b) are the most commonly used; system (c) is used only occasionally. The method of fermentation used in (b) is mostly of an uncontrolled and mixed character. Lactic acid producing bacteria are responsible for the fermentation.

Fermentation of cereals can have the following advantages:

- **Organoleptic:** Because of the production of lactic, acetic, and butyric acids (Banigo and Muller 1972) and of other metabolites, an acceptable flavour is developed.

- **Viscosity:** Fermented porridges cook more easily and have a lower viscosity (Mbugua 1987); higher levels of dry matter can therefore be achieved, and acceptable viscosity maintained in the final product.
- **Nutritional:** During 24 h-fermentation, some vitamins, such as thiamine, riboflavin, and niacin, are synthesized (El Tinay 1978); the splitting of proteins results in the increase of free amino acids, including lysine, methionine (Fernandes et al. 1987), and tryptophan (Mbugua 1987); fermentation could also reduce the content of antinutritional components such as tannins and phytic acid (Muller 1981), and possibly of trypsin inhibitors; interestingly, it has been found as well that in aflatoxin-contaminated sorghum, 63% of aflatoxin B1 was removed during the fermentation of "ogi" (Dada and Muller 1983).
- **Preservative effect:** Because of the acidity and presence of organic acids in lactic fermentation, the growth of several pathogenic and spoilage-causing bacteria is inhibited.

This last aspect might be particularly interesting, in view of the fact that the porridge comes easily into contact with pathogenic microorganisms from water or equipment, or through handling, even with hygienic preparation under household conditions. Also of interest is the common practice of keeping leftovers; storage periods may be as long as 6-8 h at room temperature (25-30°C). In the Gambia, it was found that nonfermented traditional weaning foods contained high levels of pathogens after such storage (Rowland et al. 1978).

The potential advantages of lactic fermentation have been reported by Alnwick (1986). Our research was partly inspired by his recommendations for research into the capacity of fermented porridges to protect the consumer against pathogenic microorganisms. Although fermentation offers many interesting nutritional and safety benefits, we should accept the fact that the activity of microorganisms requires energy and nutrients; as a consequence, fermentation will, to some extent, decrease the total amount of energy in the food (Muller 1981); losses will also be caused in protein (El Tinay 1978) and in vitamins. It therefore remains necessary to find processes that reduce such losses as much as possible.

Composite Weaning Foods

The weaning period is that in which the infant progresses "gradually" from exclusive breastfeeding to consumption of the full adult diet. The appropriateness of a weaning food can be determined by a consideration of the following factors: the target group - its particular nutritive requirements and its intake capacity; the ingredients and their nutritive value; and the physical, organoleptic, and cultural acceptability of the food as prepared.

Infants require complementary feeding from around the age of 4-6 months (Waterlow 1981). A gradually increasing provision of complementary food causes a concomitant reduction in the child's dependence on breast milk; this reduction continues until the child can fulfill all his or her nutritional needs with an adult diet. Apart from nutritional concerns, the development of certain physical

skills (the chewing and swallowing of relatively large quantities of solid food) determines the type of food that is appropriate at a particular age; the maximally problematic age is about 9-12 months, when an already considerable nutritional demand coincides with a still limited ability in masticating and in swallowing, and with a limited stomach capacity (Waterlow and Payne 1975). Studies have been conducted that establish standards for energy and protein requirements (Klaver 1985); if a food or meal has a net protein content of 7.8% of the total energy value, this food or meal will satisfy the protein needs of almost all children aged 9-12 months, provided enough of the food is eaten to satisfy the energy requirements. Energy intake, therefore, assumes predominant importance; this coincides with current thinking about the etiology and prevention of PEM.

The main energy component in weaning foods and diets is starch from the cereal or tuber used as the culturally acceptable staple food. The swelling of starch during cooking causes a significant increase in the volume of the food; given the constraints of feeding frequency and stomach capacity, it therefore becomes impracticable to rely on this food to cover all the energy needs of the child (Nicol 1971). Increasing the dry matter content will increase the consistency and thus give a product that is unacceptable to the child who cannot yet consume solid foods. The following are two technologically simpler methods for overcoming this problem: first, the addition of edible oil or fat (Dearden et al. 1980); and second, the use of cereal malt (Brandtzaeg et al. 1981). Both techniques result in a lower viscosity and therefore permit the consumption of a meal with a higher nutritional content per unit of volume. Allowing for the constraint of feeding frequency, higher energy intakes are thus achieved.

The constraint of feeding frequency is, at least in part, culturally determined. Unless the possibilities for food preservation have been considered, it will, in many instances, remain unrealistic to advise more frequent feeding. We consider in this paper the usefulness of simple fermentation technologies for the preparation of nutritionally adequate weaning foods that can be preserved safely and therefore kept ready for more frequent feeding.

Formula Calculation

Ingredients used in this study were white sorghum flour, ground pigeon pea, groundnut meal, groundnut oil, and malt made from white sorghum grain. The approximate composition of these ingredients was obtained from food tables (Platt 1962; FAO 1970, 1986); energy, protein, and dry matter were determined by laboratory methods. Energy contents were calculated, taking digestibility into account for a determination of metabolizable energy. Optimal proportions of ingredients were determined by principles of complementarity among amino acid patterns (Klaver 1985). Desirable quantities of ingredients were derived from recommendations of energy intakes. The groundnut oil and sorghum malt were added to the mixtures in quantities that would cause a spread of 5-6 cm diameter at 45°C within 1 min from a cylindrical (2.5 cm diameter; 7 cm height) starting position, using the Adams Consistometer (Szczesniak 1972).

The compositions of the mixes are given in Table 1, together with their nutritive values for energy and protein. The energy density is

Table 1. Composition and nutritive value of sorghum-based composite mixes.

Ingredient	S-PP-O-M ^a	S-PP-M ^a	S-GN-O ^a	S-GN-M ^a
Sorghum flour (%)	11.6	16.9	6.6	10.0
Pigeon pea meal (%)	4.3	2.8	-	-
Groundnut meal (%)	-	-	8.0	7.7
Groundnut oil (%)	2.4	-	0.8	-
Sorghum malt (%)	0.2	1.2	-	0.2
Water (%)	81.5	79.1	84.6	82.1
Energy (kcal/100 mL)	83	79	77	82
Net usable protein g/100 mL)	1.6	1.5	1.5	1.6

^aS, sorghum; PP, pigeon pea; GN, groundnut; O, groundnut oil; M, sorghum malt.

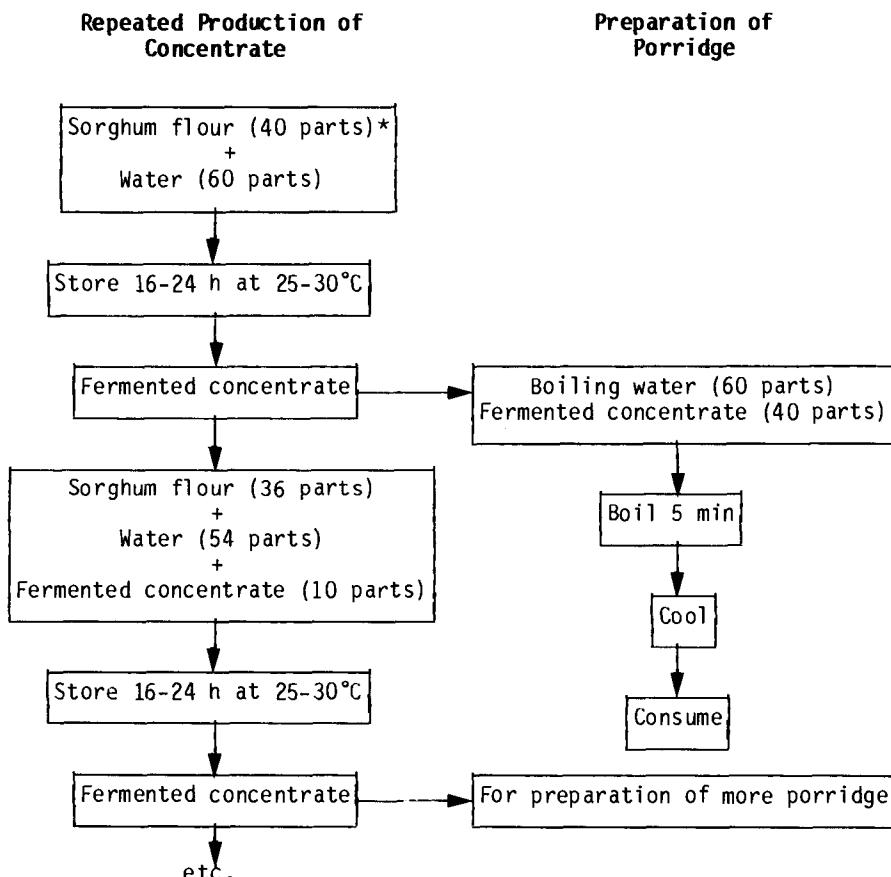


Fig. 1. Fermentation of sorghum flour and preparation of porridge. * , parts by weight.

around 80 kcal/100 mL. An infant of 9 months has a stomach capacity of about 275 mL (Tomkins 1986); one feeding therefore allows an energy intake of 220 kcal, and a utilizable protein intake of 4.3 g.

Controlled Lactic Fermentation of Sorghum Flour

Figure 1 presents a simple technique for controlled lactic fermentation; this technique can be carried out at the household level. Each day, a small quantity of the fermented concentrate is used as a starter for the next fermentation. The remainder is used for porridge preparation. This is an established method in traditional fermentation technology called "back-slopping." If we continue in this way by using approximately 3-10% of the previous batch as a starter for the next fermentation, a gradual selection of microorganisms will take place, favouring those organisms that grow best at low pH and under near-anaerobic conditions.

The effect of this fermentation procedure on the acidity is summarized in Table 2. After three repetitions of back-slopping, we see that the pH is considerably lower (3.8-4.0) than that of fresh flour or of a mixture fermented only once; the acidity (caused mainly by lactic and acetic acids) is higher (about 0.85%, calculated as lactic acid).

This stabilization of the souring by back-slopping is presented in Fig. 2. Our earlier experiences with the stabilized souring of soybeans (Nout et al. 1987) has shown that the back-slopping method is reliable over long periods, and that occasional interruptions (caused, for example, by public holidays) do not necessarily influence its dependability. Table 3 shows that after a few repetitions of back-slopping, the composition of the microflora undergoes a significant shift toward the lactic acid producing bacteria; some yeasts will also remain present. On the other hand, Enterobacteriaceae gradually disappear, as will the aerobic epiphytic flora of sorghum. (This latter includes, for example, moulds and bacteria of the genus Bacillus, that can cause spoilage or food poisoning or both.)

The described method of back-slopping offers a predictable and rapid lactic fermentation and can be carried out under simple household conditions. Although we refer to it here as a "controlled lactic fermentation," there is no requirement for the maintenance and handling of microbial pure cultures; rather, the principle of natural selection is employed. An alternative method of lactic fermentation is the use of pure culture starters under sterile process conditions:

Table 2. Effect of lactic fermentation on pH and acidity of sorghum (40% flour, 30°C 24-h intervals, back-slopping 3%).

	pH	Acidity (% w/w) (expressed as lactic acid)
Fresh flour	6.52	0.17
Fermented once	4.15	0.60
Back-slopped 3 times	3.90	0.85

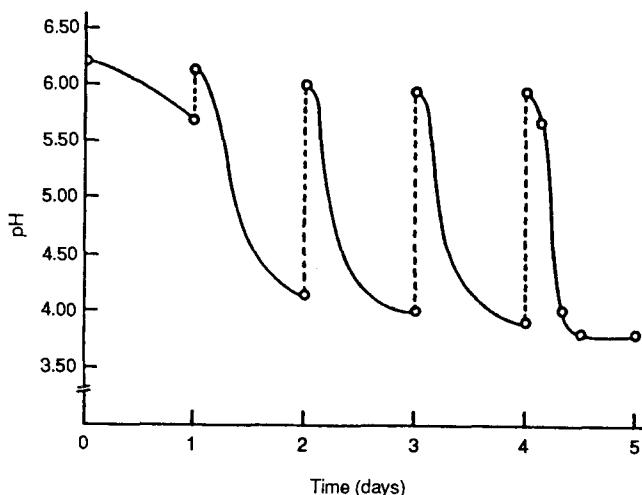


Fig. 2. Lactic fermentation of sorghum (back-slopping 3%; 30°C).

an example of this method is the lactic fermentation of maize "ujii" with pure cultures of *Lactobacillus bulgaricus* and *Streptococcus thermophilus*, carried out successfully by Mbugua (1987); this technique would be suitable for the controlled conditions of large-scale industrial operations.

Table 3. Selection of microflora during back-slopping lactic fermentation of sorghum at 30°C (40% flour in mixture)
(colony forming units; counts expressed as log N/g).

Microflora ^a	Fresh sorghum flour	Number of fermentation cycles			
		1	2	3	4
Total aerobic bacteria (PCA)	4.7	> 7.0	> 7.0	10.0	9.6
Enterobacteriaceae (VRBG)	3.0	6.5	< 1.7	< 1.7	< 1.7
Yeasts and fungi (OYEG)	2.7	6.5	7.5	7.7	7.7
Lactic acid bacteria (MRS)	4.2	> 8.0	9.1	9.7	9.7
<i>Lactobacillus</i> (Rogosa)	3.4	> 8.0	9.0	9.5	9.5

^aPCA, Plate Count Agar; VRBG, Violet Red Bile Glucose agar; OYEG, Oxytetracycline Yeast Extract Glucose agar; MRS, de Man, Rogosa, and Sharpe agar.

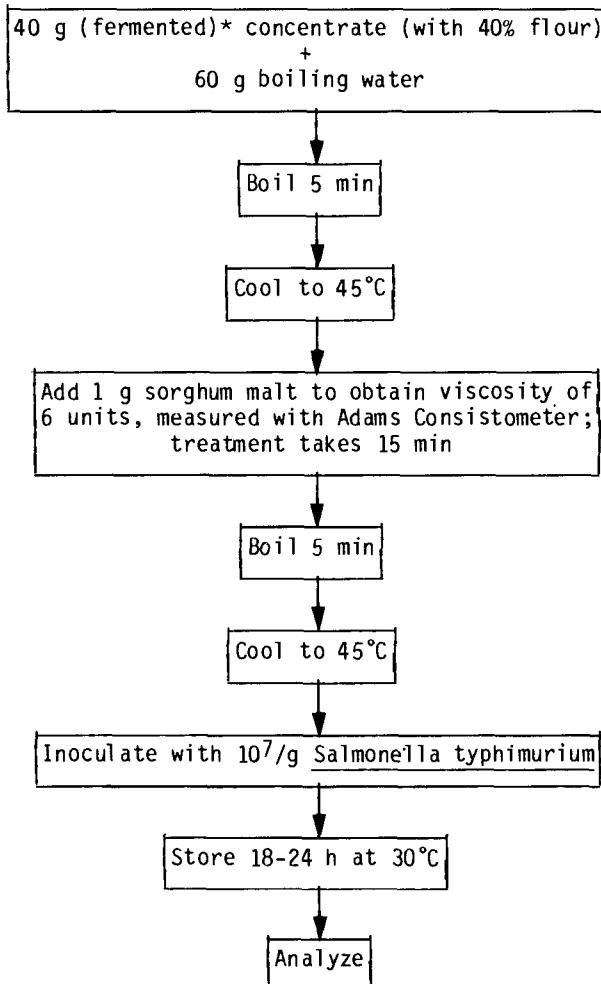


Fig. 3. Experimental procedure for porridge-making and stability testing. *, optional treatment.

Microbiological Stability of Sorghum Porridge

To study the effect of lactic fermentation on microbiological shelf-life, sorghum porridge with about 15% dry matter was prepared according to the flow sheet given in Fig. 3. During this manufacturing process, sorghum malt was added to liquefy the thick gelatinized paste; this resulted in the desired consistency of 6 units, measured with an Adams consistometer. The thinned porridge was then boiled again to stop the enzymatic liquefaction and to cook the malt.

Relevant microbiological counts from the freshly prepared porridge are presented in Table 4; these show very low levels of live microorganisms, representing only some surviving heat-resistant bacterial spores. In terms of safety, therefore, the feeding of

Table 4. Microbiological composition of freshly cooked and cooled sorghum porridge (counts expressed as log N/g).

Microflora ^a	Using fresh sorghum flour	Using lactic fermented sorghum concentrate
Total aerobic bacteria (PCA)	1.8	less than 1.7
Enterobacteriaceae (VRBG)	less than 1.7	less than 1.7
Yeasts and moulds (OYEG)	less than 1.7	less than 1.7
Lactic acid bacteria (MRS)	less than 1.7	less than 1.7

^aPCA, Plate Count Agar; VRBG, Violet Red Bile Glucose agar; OYEG, Oxytetracycline Yeast Extract Glucose agar; MRS, de Man, Rogosa, and Sharpe agar.

freshly cooked porridge is recommended. Because of the potential for rapid spoilage, the keeping of leftovers is not recommended. We must, however, respect those situations in which food is precious and therefore difficult to discard.

It becomes important, therefore, to know more about the behaviour of microorganisms in stored porridge. To test the microbiological stability of porridges, we placed them under the worst possible conditions - 30°C for 24 h. However exaggerated these conditions may appear, they provide a certain factor of security and are valid for use in tropical climates.

Under domestic conditions, it will be difficult to avoid microbial contamination of the porridge during feeding. Fortunately, the presence of one or two live microorganisms in the porridge at the time of feeding is usually not a matter of concern. On the other hand, if storage facilities are inadequate and the porridge is kept at ambient temperature for some time, those few microorganisms will multiply rapidly, causing spoilage, public health hazards, or both. To test the products under adverse storage conditions, we simulated unhygienic handling by introducing *Salmonella typhimurium* (phage type II 505 ex RIVM (National Institute of Public Health, The Netherlands) isolated from patients' stools and rendered resistant to 200 ppm nalidixic acid) into the porridge at the beginning of the storage period.

Table 5 shows that in sorghum porridge made with fresh sorghum flour, the high pH (6.35 after preparation) permitted the germination and growth of heat-resistant spores of spoilage-causing bacteria (see PCA), even when the porridge had not been inoculated, and even when it was maintained under sterile conditions. When *S. typhimurium* was added after preparation, these multiplied quickly during storage (see PCA + NA, VRBG + NA).

High counts of bacteria such as *Escherichia coli* and *Bacillus cereus* were found in stored, nonfermented traditional Gambian weaning foods (Rowland et al. 1978). Also reported was the severe contamination of Kenyan children's food with Enterobacteriaceae and *Staphylococcus aureus* (van Steenberg et al. 1983). Unfortunately, neither of these reports gives pH data of the tested samples; further analysis of the pH effect is, therefore, impossible.

Table 5. Microbiological stability of sorghum porridges (counts after 24-h storage at 30°C, expressed as log N/g).

	Using fresh sorghum flour		Using lactic-fermented sorghum concentrate	
	Not inoculated	$10^7/\text{mL}$ <i>S. typhimurium</i> added	Not inoculated	$10^7/\text{mL}$ <i>S. typhimurium</i> added
Total aerobic bacteria				
PCA	6.7		< 1.7	
PCA+NA		8.8		< 1.7
Enterobacteriaceae				
VRBG	< 1.7		< 1.7	
VRBG+NA		8.8		< 1.7
Lactic acid bacteria				
Rogosa	< 1.7	< 1.7	< 1.7	< 1.7
pH after boiling	6.35	6.35	4.25	4.29

Note: NA, 100 ppm nalidixic acid; PCA, Plate Count Agar; VRBG, Violet Red Bile Glucose agar.

In contrast, the pH of the porridge made from lactic-fermented sorghum was 4.25 after preparation. Under these circumstances, heat-resistant spores would not germinate. (Enough of the added *S. typhimurium* ($10^7/\text{g}$) were destroyed that it was below the detection level during storage (see VRBG+NA)).

Stability After Addition of Supplementary Ingredients

Sorghum-composite mixes differ from sorghum with respect to their chemical composition and physical properties. In this study, only the following composite foods (presented in Table 1) will be considered:

- S-PP-O-M: sorghum-base, supplemented with pigeon pea and groundnut oil, and liquefied with sorghum malt;
- S-PP-M: sorghum-base, supplemented with pigeon pea, and liquefied with sorghum malt;
- S-GN-O: sorghum-base, supplemented with groundnut and groundnut oil (no further liquefaction required); and
- S-GN-M: sorghum-base, supplemented with groundnut, and liquefied with sorghum malt.

To investigate the effects of pigeon pea and groundnut, we used mixtures based on fermented sorghum concentrate and corresponding mixtures based on fresh sorghum flour. Pigeon pea meal, groundnut meal, or groundnut oil was added to the sorghum base just before the porridge was to be cooked. If required, the product was liquefied with the predetermined quantity of sorghum malt. Finally, the product was heated again to obtain a well-done porridge, as outlined in Fig. 3.

It is to be expected that the introduction of nonfermented ingredients will increase the pH of the resulting porridge, particularly if fermented sorghum concentrate is used as a basis. The extent of this pH increase depends on the quantity of ingredients added and on their buffering capacity. In our mixes containing groundnut, the final pH was higher than in the mixes with pigeon pea, due to the fact that greater amounts of groundnut than of pigeon pea were used in the recipes.

Microbiological data (Table 6) show that all products made with fresh sorghum flour permitted a rapid growth of heat-resistant bacterial spores and of added *S. typhimurium*. When lactic-fermented sorghum was used as a basic ingredient, however, the bacterial spores could not grow during storage, and the added *S. typhimurium* were to some extent destroyed. In this respect, mixture 2 was more effective against added *S. typhimurium*. Because of their relatively high initial pH values, mixes 3 and 4, with lactic-fermented sorghum, were not effective against *S. typhimurium*.

These experimental findings lead to an important conclusion. We see that it is possible to maintain the microbiological stability of lactic-fermented sorghum porridge, even if this porridge has been supplemented with certain fresh, high-protein ingredients. The choice of supplementary ingredients is important: their addition must not lead to final pH values (≥ 4.5) that permit the germination or growth of undesirable microorganisms.

Table 6. Microbiological stability of sorghum-based composite mixes, with supplementary ingredients added during porridge preparation (counts after 24-h storage at 30°C, expressed as log N/g).

	Not inoculated		<i>S. typhimurium</i> inoc.		
	pH after boiling	Total bacteria	Enterobacteriaceae	$10^7/g$ af- ter 24 h	$10^3/g$ af- ter 72 h
Using fresh sorghum flour^a					
S-PP-0-M	6.50	8.0	<1.7	9.2	9.4
S-PP-M	6.35	8.3	<1.7	8.9	8.9
S-GN-0	6.65	8.4	<1.7	9.2	8.9
S-GN-M	6.52	8.9	<1.7	9.0	8.8
Lactic-fermented sorghum concentrate^a					
S-PP-0-M	4.70	<1.7	<1.7	6.0	<1.7
S-PP-M	4.45	1.9	<1.7	3.2	<1.7
S-GN-0	5.45	7.5	<1.7	8.9	6.9
S-GN-M	5.12	1.8	<1.7	7.6	9.0

^aS, sorghum; PP, pigeon pea; GN, groundnut; 0, groundnut oil; M, sorghum malt.

Fermentation of Sorghum-Based Composite Mixes

A factor of significance in the promotion of improved weaning foods is the packaging and distribution of ready-made mixtures such as that of sorghum flour and pigeon pea meal or sorghum and groundnut. Such composite mixes could then be fermented at the household level. As was demonstrated, it is fairly easy to obtain a stable lactic fermentation of sorghum flour under simple household conditions.

We investigated the use of such ready-made weaning mixtures. Using the simple procedure outlined earlier (Fig. 1), we obtained the results presented in Table 7; these results indicate that a strong lactic fermentation can be readily obtained in composite mixes. At 30°C, pH values of 3.65 (S-PP) and 3.75 (S-GN) were reached after 12 h, with the stabilized system in which a portion of 10% was used every day for back-slopping. The development of the microflora in the fermenting composite flours followed the same trend as shown earlier in Table 3 for fermenting sorghum flour. The fermented composite flours were also processed into porridges. The required viscosity of the porridges was obtained using predetermined quantities of sorghum malt.

Table 8 shows that with both composite flours (S-PP and S-GN), lactic fermentation resulted in porridges (S-PP-M and S-GN-M, respectively) that caused the rapid destruction of added Salmonella. We have, therefore, results from two processes: in one of these

Table 7. Lactic fermentation of sorghum-based composite flours by back-slopping method at 30°C; 10% inoculum; 24-h intervals (counts expressed as log N/g).

Days back-slopped	Final pH	Total bacteria (PCA)	Enterobacteriaceae (VRBG)	Yeasts (OYEG)	Lactobacillus (Rogosa)
S(85.8%)-PP(14.2%)					
0 (fresh)	6.20	4.5	3.6	2.7	3.7
1	4.25	9.6	4.1	5.8	9.4
2	3.70	9.6	<1.7	7.1	9.5
3	3.70	9.8	<1.7	7.7	9.8
4	3.65	9.8	<1.7	7.2	9.7
5	3.65	10.0	<1.7	7.3	9.7
S(56.5%)-GN(43.5%)					
0 (fresh)	6.40	4.5	3.8	2.3	4.3
1	4.29	9.6	3.9	5.4	9.1
2	3.81	9.6	<1.7	7.3	9.3
3	3.75	10.0	<1.7	8.2	9.9
4	3.75	9.7	<1.7	7.9	9.8
5	3.75	10.0	<1.7	8.0	9.9

Note: PCA, Plate Count Agar; VRBG, Violet Red Bile Glucose agar; OYEG, Oxytetracycline Yeast Extract Glucose agar; S, sorghum; PP, pigeon pea; GN, groundnut.

Table 8. Microbiological stability of sorghum-based composite mixes from ready-made composite flours (counts after 24-h storage at 30°C, expressed as log N/g).

	pH after boiling	Not inoculated		Inoculated
		Total bacteria	Enterobacteriaceae	$10^3/g$ <i>S. typhimurium</i>
Using fresh composite flour^a				
S-PP-M	6.32	8.4	< 1.7	9.3
S-GN-M	6.50	8.7	< 1.7	9.5
Using lactic-fermented composite flour^a				
S-PP-M	3.75	3.6	< 1.7	< 1.7
S-GN-M	3.85	3.8	< 1.7	< 1.7

^aS, sorghum; PP, pigeon pea; M, sorghum malt; GN, groundnut.

processes, ready-made composite flours undergo lactic fermentation before porridge-making; in the other, the lactic-fermented sorghum base is supplemented with fresh ingredients during porridge-making. The data indicate that from a microbiological point of view, better results (much safer products) are obtained from the first of these processes.

Discussion

Our experiments were carried out with white sorghum, pigeon pea, and groundnut. These are dietary ingredients that are appropriate to many African communities; we feel, nevertheless, that we must broaden our data by studies of other staples and potential supplements. Although the scope of the present data may be limited, in our opinion these data indicate interesting prospects for the production, both at the household and at the large-scale level, of porridges of high nutritional quality and inherent microbiological safety.

Mention has been made elsewhere of the positive effect of lactic fermentation on the nutritional value of cereal products. Unfortunately, these data relate to products other than weaning foods. There is, therefore, a need for a more integrated research approach.

- Comprehensive chemical analyses are needed, covering macro- and micro-nutrients, as well as possible enzymatic conversions of antinutritional components such as phytic acid or tannins, and removal of contamination with, for example, aflatoxins.
- Tests for acceptability should be conducted, and efforts made at product development. Priority should be given to operational aspects at the household level. Such products could, however, be subjected to large-scale market trials as well, with control groups receiving nonfermented products of the same composition.

The monitoring of intake, weight gain, and nutritional status during some months of consumption by experimental and control groups could make a scientific contribution to the improvement of child nutrition.

- Investigations should be made into the therapeutic or prophylactic effects of regular consumption of lactic-fermented porridges.

It has been reported that in pigs and ducks, the colonization of the gut by pathogenic *Salmonella* sp. can be reduced using lactic-fermented feed ingredients (Fuller 1986). Little is known, however, about the bacteriological basis of these effects. Similarly, lactic-fermented foods have been associated with such beneficial effects in humans as curing of diarrhea, improvement of lactose metabolism, and activities that are anticholesteremic and even anticarcinogenic (Fernandes 1987). Lack of solid experimental data makes it impossible, however, to predict whether such benefits could be expected from the regular consumption of lactic-fermented cereal porridges. In our view, one research priority should be to study the effect of lactic-fermented porridges on the essential as well as on the undesirable components of the human gut microflora, on gain in bodyweight, and on the activity of selected enzymes of metabolic significance.

Conclusions and Recommendations

- The controlled lactic fermentation of porridge ingredients resulted in highly effective protection against the growth of *S. typhimurium* contamination and against the germination and growth of heat-resistant bacterial spores.
- There should be an investigation into the effect of this fermentation on other genera of the *Enterobacteriaceae*, as well as on certain of the more acid-tolerant toxicogenic bacteria such as *Staphylococcus aureus*.
- Research should also be undertaken into the influence of lactic fermentation on the nutritive value of the porridges and the effect of these porridges on the composition of the gut microflora.
- Appeals should be made to potential sponsoring agencies to enable pragmatic, fundamental research programs to be carried out. In this respect, the scientific networks can be a valuable tool: they can help to promote the exchange of new findings, to establish cooperation projects, to facilitate staff exchange, and to coordinate field trials.

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