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Accelerated natural lactic fermentation of infant food formulations

M. J. R. Nout. F. M. Rombouts. and G. J. Hautvast

It has been estimated that more than 15 million infants and children under five years of age die annually in the tropical regions of the world [1]. In 1985, 18 African and 6 Asian countries had a child survival index of < 80% [2]. Mortality and morbidity rates of diarrhoeal diseases are highest at < 1 year [3], especially during the period that weaning foods are introduced to supplement and to succeed breastfeeding. A major role in child mortality is played by combinations of diarrhoea! diseases, nutrient malabsorption, and malnutrition. It has been estimated on the basis of 1980 data that acute diarrhoea! diseases accounted for approximately 109 episodes of disease and 4.6 million deaths of children under five years old in the developing world [3].

In addition to bacterial intestinal pathogens causing infectious diarrhoea, viral (e.g., human rotavirus) [4] and parasitic infections [5] may cause chronic or acute diarrhoea [6, 7] or may contribute to malnutrition [8]. Although the genera *Salmonella, Campylobacter, Shigella, Vibrio, Yersinia, and Escherichia* are mostly associated with bacterial diarrhoea! diseases [3, 5], other enterotoxigenic genera, including *Pseudomonas, Enterobacter, Klebsiella, Serratia, Proteus, Providencia, Aeromonas, Achromobacter, and Flavobacterium*, have also been implicated [9]. That food and food handlers play an important role as vectors for infective diarrhoea has been demonstrated [5, 9, 10].

Although any human being risks a food-borne infection after consumption of contaminated food or water, epidemiological evidence shows that the groups that are particularly at risk are those who are weak or in a poor nutritional condition [11]. Such persons are mainly infants, young children, the sick, and the elderly.

Most weaning food is prepared by boiling its ingredients in water. Although most microbial contaminants will be inactivated as a result, heat-resistant parasitic cysts and bacterial endospores may survive. Even more important, recontamination of the cooked weaning food is very likely to occur from utensils, handling, insects, faeces, etc. before it is consumed [10]. Whether this will lead to microbial growth and turn wholesome food into a health hazard depends on the nature of the contamination, the culture medium provided by the food, and its storage conditions.

Rowland et al. [10] stressed that weaning foods for tropical use must be "reasonably resistant to bacterial overgrowth for at least the 1-2 hours when the infant is likely to be feeding." Possible interventions for diarrhoeal disease control include promoting improved practices for the preparation of weaning foods [12]. In this paper we consider the usefulness of simple fermentation technologies in order to arrive at nutritionally adequate ready-to-feed weaning foods that can be preserved safely.

Lactic acid fermentation of cereal products is practised widely in African countries as a household-level food technology. Products such as ogi [13], mahewu [14], and uji [15] are popular drinkable sour gruels and are widely used throughout the day by young and old. The acceptance of this type of product offers an opportunity to stimulate the consumption of sour fermented products for hygienic reasons.

For the evaluation of the microbiological safety of the experimental products, we have opted for a worst case approach-i.e. storage for 24 hours at 30°C. The environmental changes caused by fermentative acidification in a variety of ingredients and mixtures and the effect on bacterial contaminations will be demonstrated.

TABLE 1. Formulas of high energy and protein infant foods (composition per 100 g),and accelerated acidification of their basic ingredients

Formula number	Ingredients (g)										Metabo lizable energy (kcal)	Metabo lizable protein (g)	Net protein energy (%)	Acidification[a] (ph)		
	White sorghum	Japanese millet	Pigeon Peas	Cow peas	Ground-nuts	Red kidney beans	Milk powder	Ground-nul oil	Sorghum malt	Water				0	1	S
1	23.13		4..57						1.0	71.3	103.6	3.48	13.6	6.07	4.10	3.65
2	23.04			4.69					1.0	71.3	103.6	3.59	14.0	6.14	4.34	3.71
3	12.61				9.84				1.0	76.6	103.6	3.12	12.2	6.27	4.22	3.76
4	23.75					3.99			1.0	71.3	103.6	3.60	14.1	6.09	4.09	3.73
5		22.95	4.29						1.0	71.8	103.6	3.31	12.9	5.94	4.03	3.71
6		22.87		4.41					1.0	71.7	103.6	3.42	13.3	6.06	4.01	3.74
7		12.86			9.51				1.0	76.6	103.6	3.04	11.9	6.20	4.38	3.84
8		23.53				3.74			1.0	71.1	103.6	3.42	13.4	6.01	4.00	3.98
9	12.19				9.39				0.24	78.2	100	1.95	7.9	6.40	4.29	3.75
10	8.57				10.39			1.04		80.0	100	1.95	7.9	6.45	4.30	3.75
11	21.39		3.54						1.52	73.6	100	1.90	7.7	6.20	4.25	3.65
12	13.98		5.18					2.9	0.24	77.7	100	1.93	7.8	6.10	4.10	3.65
13	17.2		6.3				1.6		1.0	74.0	94	4.14	19.3	6.37	5.00	3.80
14	17.5		4.4				3.1		1.0	74.0	95	4.36	20.1	6.59	5.04	3.90
15	17.5		1.3				6.3		1.0	74.0	95	4.92	22.7	7.05	5.20	4.05
16	15.6						9.4		1.0	74.0	95	5.5	25.5	6.90	5.92	4.08

a. pH level of mixture of 40% dry flour and 60% water at the following stages;0 = fresh mixture in start elf first fermentation cycle; 1 = end of first cycle (after 24 hours' incubation); S = stabilized level, reached after three to five fermentation cycles (measured at end elf seventh cycle).

Materials and methods

Materials

Ingredients

The cereals tested were white and red sorghum varieties (*Sorghum bicolor ssp. caffrorum*), white feterita sorghum (*Sorghum bicolor ssp. caudatum*), Japanese millet (*Echinodoa frumentacea*), bulrush millet (*Pennisetum typhoides*), finger millet (*Eleusine coracana*), and polished white long-grain rice (*Oryza saliva*). The tubers tested were sweet cassava (*Manihot esculenta*), imported deep-frozen from Thailand, and sweet potatoes (Ipomoea batatas), imported fresh from Surinam. The legumes tested were pigeon peas (*Cajanus cajan*), cow peas (*Vigna unguiculata*), groundnuts (*Arachis hypogea*), and red kidney beans (*Phaseolus vulgaris*). The vegetable oil used was commercially available groundnut oil, obtained by expeller expression. Malt was prepared from white sorghum as described under "Methods." below. Milk power containing 1% fat and 4.5% moisture was used, prepared commercially by spray-drying at moderate temperature (90°C). Refined cane-sugar was used.

Microbial cultures

Salmonella typhimurium II 505 (resistant to 200 ppm nalidixic acid) and *Staphylococcus aureus* S6 (SEA, SEB) were kindly provided by the National Institute of Public Health and Environmental Protection, Bilthoven, Netherlands. *S. typhimurium* was maintained in brain-heart infusion broth (BHI, Gibco, Scotland, No. 152-0680) with 200 ppm nalidixic acid (Sterling-Winthrop, Guildford, UK); *S. aureus* was maintained on slopes of nutrient agar (NA, Oxoid CM 3).

Methods

Calculation of weaning food formula

The approximate composition of the ingredients used was obtained from food tables [16, 17, 18]. Crude protein was determined according to AOAC method 2.055 [19], and dry matter was determined by drying to constant weight at 105°C. Energy contents were calculated taking digestibility into account for arriving at metabolizable energy.

Optimal proportions of ingredients in mixtures were determined by principles of complementarily among amino-acid patterns [20]. Desirable amounts of ingredients in mixtures were derived from recommendations of energy intakes [21]. The amounts of groundnut oil and/or sorghum malt added were chosen to achieve an end-effect of 6 cm spread of the food after 30 seconds when testing with the Adams consistometer [22].

The composition of some weaning formulas is given in table 1, together with their nutritive values for energy and protein. At an energy density of approximately 100 kcal (420 kJ) per 100 ml of porridge, children with a stomach capacity of about 275 ml at nine months old [23] will realize intakes of 275 kcal (1,150 kJ) of energy and 4.5-11 g of utilizable protein in one feeding.

Preparation of ingredients

The preparation of the raw materials is summarized in figure 1. Cereals were cleaned dry and ground to whole-grain meals using a laboratory impact mill (Pallmann type REF L18, Zweibrücken, FRG). Two methods were used for experimental tannin removal: Sorghum was dehulled by dry abrasion with a laboratory-scale rice-polishing cone (Olmia, Italy); subsequently the resulting endosperm was ground by impact milling as above. Alternatively, lye-extraction was carried out on the whole grain [24]; subsequently the grain was dried in a circulating-air oven at 50°C and ground by impact milling.

Cassava was peeled, washed, and cut into cubes of approximately 1 cm^3. Sweet potatoes were peeled by wet abrasion, washed, and mashed using a Waring blender.

Pigeon peas, cow peas, and red kidney beans were cleaned dry and ground to whole-kernel meals by impact milling as above. Groundnuts were cleaned and shredded unblanched to 1 mm particles using a household shredder (Moulinex, France).

Malt was prepared from white sorghum by soaking the grain for six hours at 20°C, discarding the water, aerating for 15 minutes, rinsing with fresh tap-water, soaking for 18 hours at 20°C, discarding the water, rinsing the grain and spreading it 1 cm thick in wet cloth, germinating for three days at 20°C until the rootless reached a length of 1.5 cm, drying in a hot-air oven at 50°C for two hours, removing the rootless by sieving, and grinding the malted grain by impact milling.

Accelerated natural lactic acid fermentation

The principle of gradual selection of lactic acid bacteria by recycling of inoculum as shown in figure I was described earlier [25]. Mixtures of flour and tap-water in a ratio of 40 g flour to 60 g water were incubated at 30°C. Fermentation cycles were 24 hours. At the start of each new cycle, material from the previously fermented batch was added as a starter at an inoculum rate of 10%. The fermented mixtures are referred to as "concentrates. "

Preparation of weaning food (*porridge*)

The preparation of the porridge is also summarized in figure 1. Using the calculated formula as a basis, an appropriate volume of tap-water was brought to a rolling

boil, and a corresponding quantity of concentrate was added gradually while stirring to avoid lumps. After boiling for 10 minutes at 100°C, the viscous mass was allowed to cool to 45-55°C; subsequently, the specified weight of malt was added and mixed by stirring. Liquefaction was allowed for 30 minutes, and the product was boiled again for 5 minutes to reduce the microbial load introduced by the malt, to inactivate the malt enzymes, and to remove the gritty mouth-feel otherwise caused by the uncooked malt, and allowed to cool. The resulting final product is referred to as "porridge."

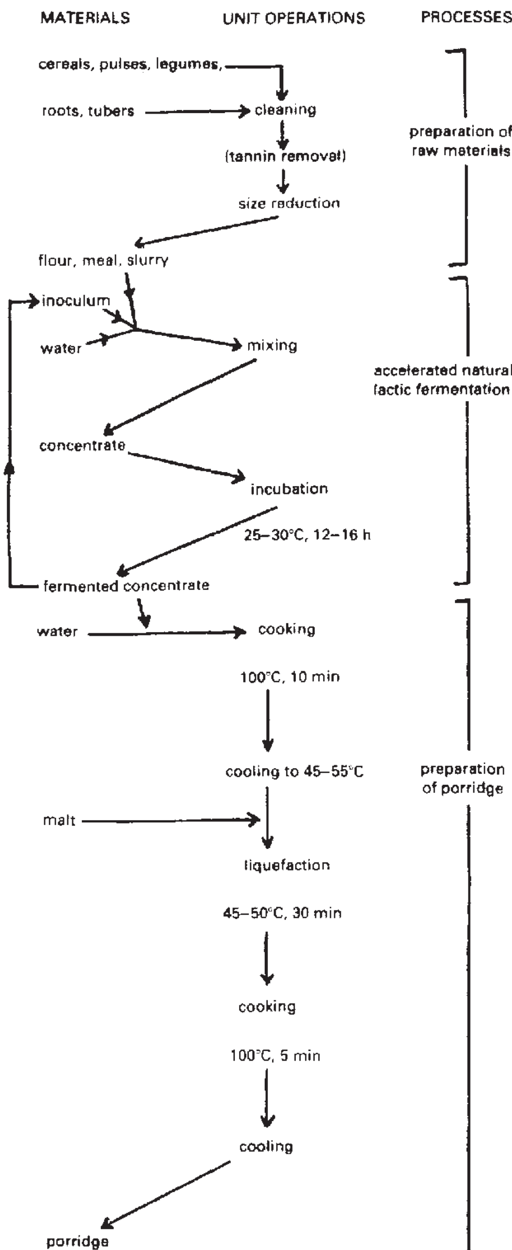

FIG. 1. Flow-sheet of fermentation and porridge preparation

Storage tests

The porridges were prepared in glass laboratory beakers. Immediately after cooking, they were covered with aluminium foil and allowed to cool to 30°C prior to incubation for 24 hours at 30°C.

Challenge tests

After preparation and cooling to 30°C, porridges were inoculated with a 24-hour 37°C BHI + 200 ppm nalidixic acid culture of *Salmonella typhimurium* or with a 24-hour 37°C nutrient broth (NB, Oxoid CM 1) culture of *Staphylococcus aureus*, and incubated at 30°C for 24 hours.

Analysis

Sampling

Experimental products were prepared in quantities of at least 0.5 kg. Samples for chemical and microbiological analysis were 50 g and 10 g respectively.

Chemical analysis

pH: An Electrofact pH meter with Schott N61 electrode was used.

Titratable acidity: A 10 g sample was mixed with 90 ml of distilled water, and 0.1000 M NaOH was added until pH 8.50 was reached, while stirring continuously. After 10 minutes of stirring, more NaOH was added to adjust the pH at 8.50, and this was repeated after another 10 minutes of stirring.

Organic acids: L(+)-lactic acid and D(-)-lactic acid were determined by enzyme assay (Cat. No. 139084, Boehringer, Mannheim, FRG). Acetic acid was also determined by enzyme assay (Cat. No. 148261, Boehringer, Mannheim, FRG). In addition, lactic and acetic acids were determined by HPLC after clarification with Carrez A and B solutions. The eluent used was 0.01 N H_2SO_4 at 30°C and 80 bar, pre-column AG50W/X4 (BioRad), column HPX-87-H (BioRad), and detector R12 * shodex RI SE-61.

Microbiological analysis

Sample preparation and determinations of total aerobic count, *Enterobacteriaceae*, yeasts, and lactic acid bacteria were as described earlier [26].

Counting of *Staphylococcus aureus* using Baird Parker medium was carried out as reported previously [27].

Counting of the nalidixic-acid-resistant strain of *Salmonella typhimurium* was carried out in pour plates of plate-count agar (PCA, Oxoid CM 325) containing 200 ppm nalidixic acid (Sterling-Winthrop, Guildford, UK)

at 37°C for 24 hours. If sublethal injury was expected, resuscitation was carried out by spreading 0.1 ml of diluted sample on thin tryptone soya agar plates (TSA, Oxoid Cm 131) and incubating for two hours at 37°C. Subsequently, a think overlay of PCA + 200 ppm nalidixic acid was applied and the material was incubated at 37°C for 24 hours.

If the numbers of *S. typhimurium* were below the detection level of the pour plates with PCA, a qualitative method was used to detect the presence or absence of viable cells. In that case, pre-enrichment from a 25 g sample in 225 ml of buffered peptone water (BPW, Oxoid CM 509) for 20 hours at 37°C was followed by selective enrichment of 0.1 ml BPW culture in 100 ml of Rappaport Vasiliadis medium (RV, Oxoid CM 669) with 150 ppm nalidixic acid for 48 hours at 42.5°C and subsequent surface streaking of plates of brilliant green agar (BOA, Oxoid CM 329) after 24 hours and 48 hours. BGA was incubated for 24 hours at 37°C. Reporting of counts and detection limits were as described earlier [26].

Results and discussion

Accelerated natural lactic fermentation

A natural lactic fermentation of uncooked cereal meal in water at 25-30°C will develop through successive dominances of aerobic epiphytes, enterobacteriaceae, hetero- and homo-fermentative *Leuconostoc, Lactobacillus, and Pediococcus spp*., resulting in acidification to pH 3.6-4.0 after two to three days. Also, some naturally occurring yeasts will be present.

In order to speed up the natural acidification process by lactic acid bacteria, daily inoculum recycling was found to be highly effective [25], realizing two advantages. Firstly, the slow natural process is accelerated by the inoculum enriched with acid producing strains of lactic acid bacteria. Secondly, the consumption of fermentable carbohydrates by aerobes and enterobacteriaceae is inhibited by the immediate dominance of lactic acid bacteria. As a result, more carbohydrate is available for lactic acid fermentation.

Figure 2 illustrates the stabilization of the acidification taking place after a few cycles of fermentation with inoculum recycling. The recycling method has been used reliably for long periods; occasional interruptions do not need to influence its dependability [25]. Table 2 shows that, after only three to five daily recyclings, the composition of the microflora was dominated by lactic acid bacteria, while some yeasts were also present. On the other hand, enterobacteriaceae could not be detected in concentrates with stabilized acidification. The described method of in oculum recycling offers a predictable and rapid lactic fermentation and can be carried out under simple household conditions. There is no requirement for the maintenance and handling of microbial pure cultures, since the principle of natural selection of naturally occurring micro-organisms is employed.

The standardization of fermentation conditions was based on experiments with whole-grain meals of a white sorghum variety, a feterita sorghum cultivar, and Japanese millet. The extent of acidification increased with higher dry-matter content of the concentrates and larger inoculum rate. Since homogenous mixing becomes difficult with higher dry-matter content, a ratio of 40 g meal to 60 g water was chosen. For reasons of economy, an inoculum rate of 10% was employed in all further experiments. The acidification rate was highest at 25-30°C. At still higher temperatures, acidification becomes irregular. In order to enable adequate stabilization in all concentrates, inoculum recycling was carried out for at least one week (seven cycles) to evaluate the fermentation of the porridge ingredients.

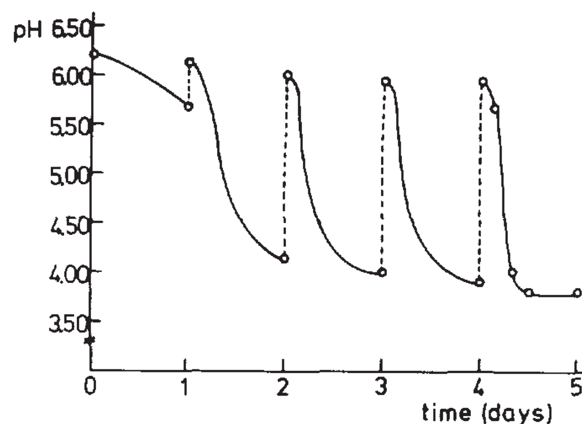

FIG. 2. Stabilization of acidification resulting in accelerated natural lactic fermentation. Conditions: white sorghum meal and water in a ratio of 40: 60; inoculum rate, 10%; incubation temperature, 30 °C.

Acidification of the basic porridge ingredients

Table 2 summarizes the acidification and microbiological composition of the fermented concentrates of basic tropical staple cereals and tubers after the first fermentation cycle and after a stabilized acidification had been achieved. Maize was not included since its acidification is well-documented [28, 29].

Since meals from the red grains (red sorghum and finger millet) resulted in less acidification than the "white" ones, it was hypothesized that the higher content of tannins in the red grains inhibits the fermentative acidification. This was confirmed in experiments with meal from red sorghum grains from which tannins had

been removed either by dry abrasive polishing or by lye extraction. A summary of the fermentation characteristics after the removal of tannins is given in table 3. Although it is possible to obtain extensive acidification after tannin removal, the required processing renders the utilization of high tannin ingredients unattractive.

TABLE 2. Aceelerated natural lactic fermentation of basic porridge ingredients

Stage[a]	Sorghum, white var.	Sorghum white feterita	Sorghumred var	Japanese Millet	Bulrush millet	Finger millet	Rice, polished	Cassava, diced	Sweet potato, wet slurry
Acidity (pH)									
0	6.15	6.50	6.07	6.13	6.15	6.05	6.18	6.25	6.30
1	5.60	5.10	4.66	5.42	4.19	4.62	3.97	4.13	4.20
S	3 95	3 71	4.27	3.65	3.65	4.10	3.46	3.83	3.85
Acidity (% w/w lactic acid)									
0	0.14	0.29	0.16	0.18	0.17	0.15	0.10	0.19	0.20
1	0.36	0.46	0.67	0.62	0.50	0.35	0.61	0.60	0.65
S	0.84	1.29	0.71	1.33	1.30	0.81	1.17	1.22	1.17
Lactic acid bacteria[b]									
0	2.6	3.8	<1.7	3.0	3.7	3.1	3.5	2.7	2.5
1	9.3	9.2	8.9	9.5	9.1	9.2	8.1	8.6	9.0
S	9.7	9.5	9.1	9.5	9.2	9.2	8.5	9.1	9.5
Enterobacteriacea[b]									
0	3.0	3.0	5.6	4.7	4.6	5.2	3.9	1 <1.7	13.1
1	6.5	5.8	7.2	4.3	7.7	7.4	5.8	4.6	7.8
S	<1.7	<1.7	<1.7	<1.7	<17	<17	<17	<17 1	<17
Yeasts[b]									
0	2.7	2.7	4.3	3.8	3.7	3.0	2.5	2.4	2.9
1	7.1	6.8	4.8	4.9	4.5	<1.7	5.3	2.8	3.5
S	7.7	7.2	6.6	7.2	6.4	<1.7	7.4	.<1.7	4.5

Concentrates containing 40% w/w dry matter; recycling (inoculum) rate.10% every 24 hours; incubation at 30 °C.
a. 0 = mixture of fresh flour and water at start of first fermentation cycle: 1 = end of first cycle (after 24 hours' incubation); S = stabilized level, reached after three to five cycles (measured at cnd of seventh cycle).
b. Expressed as '°Log colony-forming units (CFU) per gram.

TABLE 3. Influence of tannin removal on accelerated natural lactic fermentation of red sorghum concentrate

	pH			Lactic acid bacteria			Enterobacteriaceae		
	0	1	S	0	1	S	0	1	S
Untreated (control)	6.18	4.66	4.30	4.6	-	8.9	-	-	4.9
Polished by dry abrasion	6.38	3.96	3.80	3.0	-	9.3	4.8	5.4	<1.7
Soaked in 0.05 M NaOH[a]	6.42	4.05	3.88	6.1	8.9	9.3	7.2	3.7	3.0
Soaked in 0.05 M KOH[a]	6.27	3.97	3.70	6.3	8.9	9.1	7.4	<1.7	<1.7
Soaked in distilled water (control)[a]	6.04	4.41	4.23	6.2	8 7	9 0	6 0	5 7	4.5

See notes for table 2.
a. Soaked 24 hours at 30 °C.

Acidification of composite concentrates

Table 1 shows the composition of some porridges designed to contain approximately I kcal (4 kJ) of metabolizable energy per gram and a minimum of 7.8% net protein energy. The mixed dry constituents except malt and oil were made into concentrates containing 40 g of composite flour and 60 g of water. At the right in table 1, the pH values of the concentrates are shown immediately after mixing (0), after one fermentation cycle of 24 hours at 30°C (1), and after seven fermentation cycles, when stabilized acidification had been achieved (S).

It is shown that various mixtures of cereal and pulses or legume meals can be acidified successfully. After the first fermentation cycle, the pH values are still higher than 4.0. However, significantly lower pH values are achieved if the system of stabilized acidification by inoculum recycling is employed. In most cases, pH values well below 4.0 were obtained after two to four fermentation cycles.

Only if milk powder was chosen as a major ingredient did the pH in stabilized systems not decrease below 4.0. Chemical analysis of the fermented concentrates revealed that lactic and acetic acids were predominant: in formula 11 they occurred in the ratio D(-)-lactic: L(+)-lactic: acetic = 10: 13: 1. In addition, analysis of the fermented concentrates containing milk powder showed that approximately 60% of the lactose had been hydrolysed during the fermentation. This could be of interest for lactose-intolerant consumers.

Microbiological stability of the cooked final products

The microbiological stability of porridges cooked from fermented concentrates as described in the methods section, and formulated as in table 1, was evaluated in storage and challenge tests. Some representative results are presented in table 4. Formulas 9 and 11 represent simple cereal-legume mixtures.

During the storage tests, no recontamination occurred. Consequently, counts of enterobacteriaceae remained below the detection level. As evidenced by the difference in total aerobic count after storage, products from fermented concentrates strongly inhibited the outgrowth of heat-resistant bacterial endospores that had survived the cooking, whereas non-fermented products allowed their growth

Challenge tests showed a rapid growth of *S. typhimurium and S. aureus* in porridges from non-fermented concentrates. On the other hand, the inoculated bacteria died in the acidified porridges. With formulas 14 and 16 it has been shown that increasing levels of milk powder increase the pH of the resulting porridge. In storage tests, the outgrowth of surviving endospores was inhibited. In challenge tests, porridges with levels of milk powder causing pH > 4.0 were less effective in reducing the counts of inoculated *S. typhimurium and S. aureus*.

TABLE 4. Microbiological stability during storage and challenge tests of porridges cooked from non-fermented and fermented concentrates

Formula[a]	pH of porridge after boiling	Storage tests[b]		Challenge tests			
		Total Aerobic Bacteria t_{24h}	Enterobacteriaceae t_{23h}	Inoculated with S. typhimurium		Inoculated with S. aureus	
				t_0	t_{24h}	t_0	t_{24h}
Non-fermented							
9	6.32	8.4	<1.7	3.0	9.3	4.5	8.5
11	6.50	8.7	<1.7	3.0	9.5	4.4	8.5
Fermented[c]							
9	3.75	3.6	<1.7	3.0	<1.7	4.5	<2.7
11	3.85	3.8	<1.7	3.0	<1.7	5.0	<2.7
14	3.84	4.7	<1.7	7.1	<1.7	5.3	<2.7
16	4.38	2.4	<1.7	7.3	4.3	7.5	2.7
11+6%							
sucrosed[d]	3.84	2.4	< 1.7	6.9	< 1.7	7.5	<2.7

11+10%							
sucrose	3.79	2.9	<1.7	6.1	<1.7	7.3	<2.7

All counts expressed as ^{10}Log N per gram of porridge.
to = initial time; t_{24h} = after 24 hours' incubation at 30 °C
a. See table 1 for ingredients.
b. Not inoculated.
c. Porridges from concentrates acidified by accelerated natural lactic fermentation.
d. Sucrose added after preparation of porridge.

TABLE 5. Microbiological stability during storage and challenge tests of porridges obtained by cooking dehydrated fermented concentrate. and by rehydration without boiling of dehydrated precooked porridge

Formula	pH after boiling	Storage tests		Challenge test (inoculated with S. typhlmurium)	
		Total bacteria	Enterobacteriaceae		
		t_{24h}	t_{24h}	t_0	t_{24h}
11A[a]	3.88	3.50	< 1.7	4.50	<2.4 (-)[c]
11B[b]	4..00	2.9	< 1.7	3.0	<2.4 (-)

All counts expressed as ^{10}Log N per gram of porridge.
t_0 = initial time: t_{24h} = after 24 hours' incubation at 30°C.
a. Porridge cooked from dehydrated fermented concentrate. formula 11 (see table 1 for ingredients).
b. Instant porridge, reconstituted without boiling from drum-dried flakes of precooked porridge. formula 11.
c (-) = absent in 25 g by liquid selective enrichment.

In order to mask the sour taste of porridge from fermented concentrate, sugar additions of 6%-10% (porridge weight basis) are adequate. Table 4 shows that the addition of sugar to prepared porridge did not significantly affect its microbiological stability.

Dehydration of fermented concentrate

For distribution and marketing' a dehydrated product would be preferred. Several options were studied.

1. *Packaging a mixture of 90% fresh (non-fermented) flour and 10% dehydrated fermented concentrate*. At the household level this would still have to undergo a fermentation to achieve the required acidity, followed by porridge cooking. Experimental dehydration of fermented concentrate using a hot air oven with forced cross-flow ventilation could be applied to obtain products with 4%-6% moisture content and adequate residual counts of lactic acid bacteria to act as starters for fermentation. The fermentative activity of the fresh and stored dehydrated concentrates was compared with that of wet fermented concentrate, using mixtures of 90% non-fermented sorghum flour and 10% starter concentrate (dry-measure basis). Dehydration reduced the activity of the starter concentrate considerably, especially after a few weeks of storage. The pH decrease would start only after a lag time of 10-12 hours, during which period contaminating micro-organisms could have multiplied to dominance. Another disadvantage of this approach is that the product cannot be used immediately in the household since it still needs to be fermented.
2. *Packaging the dehydrated fermented concentrate*. At the household level, this could be cooked into a sour porridge immediately. Fermented concentrate of formula 11 was dehydrated in a hot-air oven. Table 5 shows the excellent microbiological stability of porridge prepared from the dried material according to the corresponding formula in table 1 (11A).
3. *Packaging a dehydrated (instant) cooked porridge*. At the household level this product could be reconstituted into porridge with cold or warm water. Cooked porridge using the same formula 11 was dehydrated by drum-drying to obtain flakes of instant porridge. The flakes were reconstituted with water of 50°C following the corresponding formula in table 1. The resulting porridge (11B) had an excellent microbiological stability, as indicated in table 5.

Although the latter two dehydrated products proved safe under laboratory conditions, it would be preferable to promote the use of option 2 (dehydrated fermented concentrate) for use at the household level, for at least two reasons. First, the cooking required to prepare porridge from this product will help to deactivate contaminations introduced by the water used, and, second, the required hot-air drying technology is considerably cheaper than the drum-drying process required for manufacturing instant porridge.

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