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Effects of energy density and sweetness of gruels on Burkinabe infant energy intakes in free living conditions

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In free living conditions, 24 breastfed infants, aged 6 to 10 months, were given successively five experimental gruels to study the effect of energy density (ED) and sweetness (sweet taste) on energy intakes (EI). Four gruels (G0, G1, G9 and G20) were prepared with experimental flours which were composed of the same local ingredients and which contained different levels of sucrose. The fifth gruel (GC) was prepared with an industrial flour. G0 had an average ED of 45 kcal/100 g (189 kJ/100 g) and the other gruels an average ED of 110 kcal/100 g (461 kJ/100 g). Although the sugar contents of the flours were 1% for G1, 9% for G0 and G9 and 20% for G20, because of flour composition and gruel dry matter content, the gruel G1 had the same sweetness as G0, G20 the same sweetness as GC and G9 a sweetness between that of G1 and G20. The results show that the amounts of G0 consumed were significantly higher than those of high ED gruels (7.84 for G0 vs 6.12, 5.63, 4.46, 4.72 g/kg body weight/meal, respectively for G20, G9, G1 and GC, $P < 0.05$). However, EI from high ED gruels were significantly ($P < 0.001$) higher than those from G0 (6.65, 6.10, 4.86, 4.83 kcal/kg/meal, respectively for G20, G9, G1 and GC vs 3.46 for G0). Energy intakes from G9 and G20 gruels were not significantly different but were significantly higher than those from GC and G1 ($P < 0.001$). So, consumption of sweet gruels with high ED and composed of local ingredients increased, at least by 76%, the EI from gruels in comparison with those from low ED gruels, but the amounts consumed by the infants remained too low to cover more than 15% of their daily total energy needs.

Introduction

In infants, from the age of 6 months, breast milk is no longer sufficient to meet their nutritional needs, therefore consumption of other foods is necessary to complement what breast milk provides (WHO, 1998). Considering infant physiological characteristics, complementary foods should have semi-liquid consistency (gruel) at the beginning of the weaning period.

In Burkina Faso, protein-energy malnutrition, in particular growth retardation, which concerns 29% of preschool children, begins between 6 and 20 months, i.e. during the weaning period (Seroussi, 1994). In this country, mothers use local flours processed in small production units or in households and prepare gruels with a fluid consistency and an energy density close to 40 kcal/100 g (Trèche *et al.*, unpublished). Given

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the very small gastric capacity of infants (30–40 ml/kg body weight/meal) (Sanchez-Grinan *et al.*, 1992) and the low gruel feeding frequency (two gruels a day), the consumption of gruels with an energy density of 40 kcal/100 g cannot provide the breast milk complements that are required to meet daily nutritional needs. Nutritional qualities, in particular energy density, are not adequate and have to be improved. Energy intakes from gruels are at a low level due to insufficient energy density and also because of mean quantities of consumed gruel which remain far lower than the theoretical infant gastric capacity (Trèche *et al.*, unpublished).

The aim of our work is to increase Burkinabe infant energy intakes from gruels without changing meal frequency. To do so, we investigate the main factors which influence intakes. Factors related to the food, to the child and to the caregivers are involved (Brown, 1997). In this study conducted from February to July 1999 in Ouagadougou, we focused on factors related to food and we studied the effects of energy density and sweetness of gruels on Burkinabe 6- to 10-month-old infant energy intakes in free living conditions. We had two objectives. The first one was to show in this context the nutritional benefit, i.e. an increase of energy intakes, of an increase of gruel dry matter content associated with a decrease in viscosity due to enzymatic treatments. This nutritional benefit has already been shown but in particular contexts such as in hospital, with infants recovering from malnutrition (Mosha and Svanberg, 1990; Sanchez-Grinan *et al.*, 1992; Rahman *et al.*, 1994, 1995; Stephenson *et al.*, 1994; Brown *et al.*, 1995; Darling *et al.*, 1995; Mensah *et al.*, 1995; Mitra *et al.*, 1995; Donnen *et al.*, 1996; Trèche, 1996; den Besten *et al.*, 1998; Bennett *et al.*, 1999). The second one was to see if it was possible to increase the average consumed quantities of high energy density gruels and consequently the energy intakes from these gruels by modifying their organoleptic characteristics such as sweetness.

Materials and methods

Gruels

Five experimental gruels were tested:

- one (G0) with the characteristics of the gruels usually consumed by infants, i.e. a low energy density of 45 kcal/100 g, a dry matter content close to 10 g/100 g and a semi-liquid consistency. This gruel was prepared with local ingredients.
- four gruels with a high energy density due to a higher ratio (amount of flour/amount of water) than G0. Three of them were prepared with local ingredients and had a different level of sweetness (low G1, medium G9, high G20). The fourth one was prepared with an industrial flour 'Cérélac' processed in the Ivory Coast and sold in Ouagadougou (GC). This flour contains mainly wheat, milk, sucrose and palm oil.

All the gruels had the same semi-liquid consistency. To characterise the consistency we used the flow which is the distance run by 100 ml of gruel at 45°C for 30 s in a Botswick consistometer. The reference consistency was that of gruels usually consumed by infants, which has a flow of 120 mm/30 s. To obtain such a flow, adding α-amylases was necessary in G1, G9 and G20. We used the industrial α-amylases (BAN 800 MG) from Novo SA.

High energy density gruels had the same energy density as GC prepared with the dry matter content leading to the reference flow of 120 mm/30 s.

To compare sweetness, organoleptic tests were performed. The sweetest gruel (G20) had the same sweetness as GC. The less sweet gruel (G1) had the same sweetness as G0. G9 which was prepared with the same flour as G0, contained more flour, so more sugar, and was in consequence sweeter than G0.

The flours used to prepare G0, G1, G9 and G20 were composed of millet, soybean, peanut, sucrose and salt. Flour compositions were defined with a formulation software, namely Alicom, created by our laboratory. To have gruels with a different sweetness, we changed the ratio millet/sucrose and we kept the percentages of soybean, peanut and salt constant. Flour compositions are given in Table 1

Infants

Twenty-four infants from an area ('secteur 30') of Ouagadougou were enrolled in the study. To be eligible, children had to be 6–10 months old, consume usually at least two gruels a day, have a weight-for-length *Z* score >–3 and no particular health problems. Parents had to give an

Table 1. Flour compositions (g/100 g)

	Flour used to prepare G0 and G9	*Flour used to prepare G1*	*Flour used to prepare G20*
Millet	66.3	74.3	55.3
Sucrose	9.0	1.0	20.0
Soybean	19.0	19.0	19.0
Peanut	5.0	5.0	5.0
Salt	0.7	0.7	0.7

informed consent for their child to participate in the study.

Procedure

Each child was given the five experimental gruels, each one for 3 days and twice a day at the usual feeding times. Each child was followed for 2.5 weeks. G0, which had the characteristics of the gruels usually consumed by children, was given first, GC was given at the end of the experimental period and G1, G9 and G20 in one of these combinations: G20–G9–G1 or G20–G1–G9 or G9–G20–G1 or G9–G1–G20 or G1–G20–G9 or G1–G9–G20. On Sunday, the intakes were not measured but the same gruel as the one given on Saturday was prepared by the mothers and given to the child.

The gruels were prepared at home by field workers in a standard way. The quantities of cold water necessary to prepare the gruel, were weighed (±0.1 g) and added to preweighed flour. The mixture was cooked on a portable gas ring. When the ebullition started, the gruel was cooked for 5 min. The infants were fed by their mother or by the person who usually feeds them. The field worker arrived 1 h before the feeding to be sure that the children did not have anything (milk, water, other foods) in the hour before the gruel intake measurements. Each day, questions were asked about morbidity (respiratory problems, diarrhoea, fever, others) and about what the children had eaten between the last experimental gruel intake and the arrival in the household of the field worker (what they had eaten, when, how often and how much). When the temperature of the gruel reached 45°C, two gruel samples were collected to measure the dry matter content and the gruel was given to the child. The bowl before and after feeding and any possible vomit were weighed on a scale with a 0.1 g sensitivity.

Children were weighed at the end of the 2.5 week period and their weight at each experimental day was estimated with the average weight gains obtained from the reference anthropometric values defined by the WHO.

Data analysis

Data were analysed with the SAS system. Values were compared within individuals for each dietary treatment by using the General Linear Models (GLM) procedure which uses the method of least squares to fit general linear models. The statistical method used to test if there was an effect of gruel characteristics on intakes was an analysis of variance (ANOVA). In the first model, the variables of the model were the infant, the day (1, 2 or 3), the meal (1 or 2) and the gruel. Variables with no significant effects were eliminated and we kept in the final model the variables infant and gruel. Student–Newman–Keuls tests were performed to compare the means of gruel and energy intakes according to the type of gruel given.

Results and discussion

Gruels

Table 2 gives the nutritional characteristics of the experimental gruels. Because of its low dry matter content, the gruel G0 had far lower lipid, protein and carbohydrate content than the high energy density gruels.

Infants

In the study area, all the children eligible to participate in the study were registered. Given their low number, all of them were enrolled in the study. A total of 11 male and 13 female infants participated (Table 3).

Intakes

We should have had 720 intake measurements, 144 per gruel and 30 per infant. Fourteen data were not able to be collected (three each for G1, GC, G0 and G20 and two for G9) so we had 706 intake measures.

In 25% of the 706 experimental meals (175 meals), infants were breastfed or drank water within an hour before the intake measures. χ^2 tests showed that according to the gruel, the

Table 2. Experimental gruel characteristics

	G0	*G1*	*G9*	*G20*	*GC*
Dry matter content[1, 2]	10.3 ± 0.8	25.4 ± 1.0	25.1 ± 1.2	25.5 ± 1.4	24.1 ± 0.7
Lipid content[1]	1.1	2.8	2.6	2.5	2.0
Protein content[1]	1.7	4.5	4.2	4.0	3.8
Carbohydrate content[1]	6.9	16.4	16.9	17.8	17.3
Saccharose[1]	1.0	0.3	2.4	5.3	NS
Energy density (kcal/100 g)	44.5 ± 3.2	109.4 ± 4.3	108.4 ± 6.8	108.6 ± 6.2	102.3 ± 3.2

[1] g per 100 g of gruel.
[2] mean ± SD of the values determinated with the 140 gruels given to the infants in the study.
NS not specified.

numbers of meals before which there were food consumptions within an hour were not significantly different. In 148/175 meals the last consumption was taken about 40–50 min before the measures, and in seven meals infants were breastfed or drank water within 5 min before the measures.

In 44.9% of experimental meals, children had health problems. They suffered mainly from respiratory problems and diarrhoea. For each gruel, Kruskal–Wallis tests showed no significant differences between the intakes on the days when infants had or had no health problems.

The statistical analysis showed that there was no significant difference between the intakes according to the day (1, 2 or 3) and the meals (first or second meal of the day).

The variance analysis and the Newman–Keuls tests revealed three groups: the first one composed by G0, the second one composed by G20 and G9, and the third one including G1 and GC. The amounts of gruel consumed from group 1 were significantly higher than those from groups 2 and 3, and the amounts of gruel consumed from group 2 were significantly higher than those from group 3 ($P < 0.05$) (Table 4). Amounts of G0 gruel consumed (7.8 g/kg/meal) were higher than those of G1, G9 and G20 (respectively, 4.5, 5.6, 6.1 g/kg/meal) and those of GC (4.7 g/kg/meal).

Energy intakes from group 2 gruels were significantly higher than those from groups 1 and 3, and energy intakes from group 3 were significantly higher than those from group 1 ($P < 0.001$) (Table 5). Despite lower consumed quantities, consumption of the high energy density gruels G1, G9 and G20 increased the energy intakes respectively by 40, 76, 92% in comparison with the energy intakes from G0 (from 4.9 to 6.6 vs 3.5 kcal/kg/meal; $P < 0.001$). With a flour containing 9% of sugar, the gruels prepared with a dry matter content of 25% (G9 gruels) led to an increase of 76% of the energy intakes in comparison with those from gruels prepared with a dry matter content of 10% (G0 gruels). One of the consequences of increasing the dry matter content of gruels was the increase in their sweetness. For this reason, we chose to test high energy density gruels with the same sweetness as G0 (G1). With G1 gruels, energy intakes were increased by 40% compared to those from G0 gruels. These results showed the

Table 3. Characteristics of children included in the study

Age (months)	7.9 ± 1.0
Weight-for-age (Z score)	−1.0 ± 0.9
Length-for-age (Z score)	−0.7 ± 0.9
Weight-for-length (Z score)	−0.5 ± 1.1

Table 4. Mean amounts of gruel consumed

	Mean (g/meal)	*Mean (g/kg/meal)*
G0	56.4 ± 27.2[a]	7.8 ± 3.9[a]
G1	32.3 ± 19.6[c]	4.5 ± 2.8[c]
G9	40.7 ± 31.2[b]	5.6 ± 4.7[b]
G20	44.7 ± 31.1[b]	6.1 ± 4.3[b]
GC	35.0 ± 34.4[c]	4.7 ± 4.7[c]

Different letters indicate significantly different means ($P < 0.05$) (Newman–Keuls test).

Table 5. Mean energy intakes from gruels

	Mean(kcal/meal) (kJ/meal)	*Mean (kcal/kg/meal) (kJ/kg/meal)*
G0	24.9 ± 11.9[a] (104.4 ± 49.7)	3.5 ± 1.7[a] (14.5 ± 7.1)
G1	35.1 ± 21.3[c] (147.1 ± 89.2)	4.9 ± 3.0[c] (20.34 ± 12.7)
G9	44.2 ± 33.7[b] (184.9 ± 140.9)	6.1 ± 5.1[b] (25.53 ± 21.5)
G20	48.6 ± 33.9[b] (203.4 ± 141.9)	6.6 ± 4.7[b] (27.8 ± 19.8)
GC	35.7 ± 34.9[c] (149.5 ± 145.9)	4.8 ± 4.8[c] (20.2 ± 20.0)

Different letters indicate significantly different means ($P < 0.001$) (Newman–Keuls test).

effect of energy density on energy intakes of Burkinabe infants in free living conditions: as was already shown in other contexts, increasing the energy density of gruels improves the energy intakes from gruel feedings (Trèche, 1996; WHO, 1998).

Energy intakes were significantly ($P < 0.001$) higher with the sweetest gruels than with G1 (6.10 and 6.65 for G9 and G20 vs 4.86 kcal/kg/meal for G1). Energy intake improvement was all the greater as sugar content was high. However, differences were not significant between G9 and G20. Thus, a flour sugar content between 9 and 20% seems optimal. An infant preference for sweetness had already been shown in Maller and Turner (1973) studies in infants of less than 1 month. In 1983, Fomon *et al.* showed in female infants of less than 4 months that energy intakes from a formula were higher when the sweetest formula was given.

The average amounts of gruel consumed were far lower than the theoretical gastric capacity of infants which is estimated at 30 ml/kg/meal (Sanchez-Grinan *et al.*, 1992). The average amount of gruel consumed was different from one child to another as is expected, but these quantities were globally very small (overall average: 5.75 g/kg/meal). Reasons why the amounts of gruel consumed were so low in children without chronic diseases, fed at home, by their mother, with gruels prepared with local ingredients usually consumed by their mother, are unknown. Energy intakes from other foods might explain this. The questionnaires about what they ate in the day showed that besides breast milk and experimental gruels, consumption of other foods was quite occasional. They showed also that breastfeeding and water-drinking frequencies were very high (respectively 11 and 8 times a day). Consequently, one hypothesis to explain the low intakes of gruel might be that usual breastfeeding frequency plays an important role in the control of gruel intake, and more generally that high feeding frequencies make infants used to consuming small quantities per meal. Flavour could explain also the low gruel intakes. In our protocol, we chose to compare the energy intakes from our experimental gruels prepared with local ingredients with those from an industrial gruel sold in Ouagadougou (GC) because we thought that the latter would be optimum and higher in quantity than the other ones. Finally, the amounts of GC consumed and the energy intakes from this gruel were below those from G9 and G20, probably because of food habits and taste preferences.

The consumption twice a day of gruels, whatever the flour used was, did not cover more than 15% of the daily energy needs of infants. In 6- to 10-month-old infants, the energy need defined by Butte (1996) is about 85 kcal/kg/day and studies conducted in different countries have shown that breastmilk covers about 60% of the daily energy needs of infants (WHO, 1998). Consequently, complementary foods should cover 40% of this requirement. In this study, two G20 feedings covered 14.8% of the daily energy needs and the contribution of complementary foods was close to this percentage because besides breast milk and experimental gruels, the infants included in this study had other foods occasionally.

Conclusion

Consumption of high energy density (110 kcal/100 g or 461 kJ/100 g) gruels prepared with local ingredients led to a 76% increase of the energy intakes in comparison with those from low energy density gruels. At the same energy density (110 kcal/100 g or 461kJ/100 g), the average consumed amounts of gruel prepared with flours whose sugar contents were respectively 9 and 20% were not significantly different but were significantly higher than those from gruels prepared with 1% sugar flour.

However, the consumption of high energy density gruels prepared with 9 and 20% sugar flours remained very low (respectively 5.6 and 6.1 g/kg/meal) and their contribution to meet the daily energy needs was only at best 15%.

Modifications of flavour associated with an increase of energy density could lead to an increase of energy intakes by increasing the consumed quantities. However, the general low amount of gruel consumed, observed in this survey, suggests that other factors such as breastfeeding and water-drinking frequency are deeply involved in the control of intakes.

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