High-energy-density gruels in the treatment of hospitalized children suffering from mainly protein malnutrition in Zaire

Philippe Donnen, Michèle Dramaix, Daniel Brasseur, Richard Bitwe Mihanda, Sekele Fazili, and Serge Treche

Abstract

The effects of the energy density of gruels on energy and protein intake and the nutrition status of 148 hospitalized malnourished children age 3 to 24 months were determined under standardized conditions. Severely malnourished children consumed significantly more high- or low-energy-density gruels than children less affected. The feeding of high-energy-density (1.0 kcal/ml) versus low-energy-density gruels (0.5 kcal/ml) allows for a significant increase in mean energy and protein intakes from gruels: 29.4 ± 2.1 (SE) versus 18.9 ± 1.4 kcal/kg/day ($p < .001$)*, and 1.10 ± 0.07 versus 0.75 ± 0.05 g/kg/day* ($p < .001$)*. The mean serum albumin concentration tended to increase more for children consuming high-energy-density gruels. These data emphasize the interest of high-energy-density gruels in the rehabilitation of severely malnourished children.*

Introduction

Protein-energy malnutrition (PEM) is a major public health concern with infants and children of pre-school age in most developing countries [1]. In Zaire, in the rural area of the Kivu region, PEM affects a large number of children from the very first months of their lives. Compared with international growth curves, the local growth curve exhibits a faltering about age three months [2, 3]. This growth retardation results mainly from the mother's PEM, which causes a significant decrease in milk secretion [4, 5] and encourages early resort to food complements [6].

Some children suffering from malnutrition have to be hospitalized. The treatment, apart from infection control and the equilibration of hydroelectrolyte disorders, is essentially dietetic. It aims at progressively providing from 80 to 175 kcal/kg of energy and from 0.70 to 5.75 g/kg of protein daily [7].

At the start of treatment, the children's main diet consists of liquid and semi-liquid foods, since most of them are anorexic and refuse any solid foods. Because cow's milk is scarce and expensive and the intestinal lactase activity of children suffering from PEM is depleted [8], a diet of gruels made from available local produce is favoured.

Weaning foods traditionally used in Africa usually have low energy density [9], because the starch they contain tends to swell during cooking, when great quantities of water are absorbed. A child whose stomach capacity is limited will feel satiated before daily energy and protein requirements have been met. Denser porridges are therefore likely to provide these children with a higher daily intake of energy and proteins.

Several techniques have been developed to increase the density of weaning foods while ensuring that their viscosity remains acceptable [10–12]. Amylase added to porridge during cooking breaks down the starch chain into smaller fragments, reducing swelling and increasing density. The present study was conducted to evaluate the impact of high-energy-density gruels on both energy and protein consumption, and on the nutrition status of hospitalized malnourished children.

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Methods

Subjects

The study was carried out at the Children's Hospital of Lwiro in south Kivu province in the east of Zaire. The inhabitants of these highlands (1,400–2,000 m) are mostly peasants. The crops are insufficient to cover the needs of the people as a result of overpopulation and soil erosion. The food supply is constantly poor in energy and periodically low in protein, depending on the season. Protein shortage is at its most acute by the end of the dry season and the beginning of the rainy season from October to the end of December [13]. Iodine deficiency has been described in some areas of this region, but not in the one concerned with this study.

Every year about 500 children are admitted to this hospital, most of them suffering from PEM. Hospital criteria used to define a state of malnutrition are a serum albumin concentration below 30 g/L measured locally by the technique of Sonnet and Rodhain [14], and/or weight-for-length below the fifth percentile of the local curve (E. DeMaeyer, unpublished data, 1959).

It should be noted that in the region under scrutiny, the median values of weight-for-age and height-for-age are strikingly lower than the international reference values, but children's weight-for-height absolute values are very similar to those of the international reference [3]. Hospital death rates vary between 11% and 18% according to year. Anthropometric, clinical, and biological data are, as a rule, obtained from all children at admission as well as during hospitalization.

All 148 children under two years of age who were admitted to hospital from May to November 1993 were enrolled in the study. They were randomly assigned to one of two groups. The control group of 74 children was fed the usual hospital food, including the traditional gruel. The treatment group of 74 children received the same food except for the traditional gruel, which was replaced by a high-energy-density gruel.

On entry and on day 7, anthropometric, clinical, and biological data were obtained. The children were weighed, naked, on a balance sensitive to 10 g. They were measured in a recumbent position to the nearest millimetre. The mid-upper-arm circumference was measured on the left arm to the nearest millimetre. Clinical signs of infection were recorded, and serum albumin concentration was measured. Criteria for recovery and consequently readiness for discharge were no oedema, weight-for-length above the fifth percentile of the local curve, serum albumin concentration above 23 g/L, and no infections.

In our previous studies, the mortality risk was not significantly higher for children with a serum albumin concentration between 19 and 23 g/L on entry than for children in whom the value was higher than or equal to 30 g/L [15]. This is one of the reasons why we allow discharge when the serum albumin concentration is above 23 g/L.

Gruels

The traditional gruel (control) is the one usually fed to children at this hospital. It is prepared locally by a dietitian from ingredients bought in the region. The high-energy-density gruel (treatment) was prepared in Brazzaville, Republic of the Congo, from mixed flours (maize, soya, sorghum) to which industrial amylase was added [16]. The composition of the two types of gruels is shown in table 1. It is calculated for 100 g of rough ingredients, i.e., the ground meal proper that is not dried.

The high-energy-density porridge contained an additional 32.5 mg of α-amylases (Ban 800 MG-NOVO Industries SA) per 100 g of dry matter. To obtain suitable viscosity, 100 g of the traditional porridge was mixed with 600 ml water, whereas to obtain an equivalent viscosity with meals containing amylase, only 250 ml water was needed. The energy densities obtained were 0.5 kcal/g for the traditional gruel and 1.0 kcal/g for the high-density gruel.

The children were fed five meals a day. The gruels were given three times. The other two consisted of locally available foods, such as fresh fish, beans, rice foufou (paste made from cassava meal and sorghum), plantain bananas, vegetables (amaranth, onions, tomatoes), and palm oil. The daily intake of gruels for each child was measured accurately during the first six days of hospitalization. The amounts consumed were measured as the difference between the amount served and the amount left in the bowl.

Three days before starting the study proper, the high-energy-density porridge was fed to a dozen hospitalized children to test its acceptability. The porridge was well tolerated, and the frequency of episodes of diarrhoea was similar in both groups over the course of the study.

A great proportion of the children were discharged on day 7 or even earlier (58% treated group, 55% controls). This was partly due to the fact that they had been hospitalized from May to the beginning of November, and enjoyed a better average nutrition status than children who were hospitalized during the period of protein shortage between October and the end of December. In addition, to reduce the risk of intrahospital bacterial contamination and avoid lengthy separations from the family environment,

TABLE 1. Composition of the two types of meals for 100 g of rough ingredients

Composition	Control	Treatment
Ingredient composition		
cassava meal (g)	—	43.4
maize meal (g)	40.0	30.0
soya flour (g)	20.0	18.6
sorghum flour (g)	20.0	—
sugar (g)	20.0	8.0
Macronutrient composition		
proteins (g)	12.9	11.3
lipids (g)	6.4	4.7
carbohydrates (g)	58.0	65.6
energy (kcal)	350	342
moisture (humidity/water) (%)	7.9	9.0

children suffering from malnutrition are not admitted to hospital for a long period of time.

Weight and length were expressed in *Z* scores calculated by comparison with international reference growth curves [17]. Given the short follow-up, growth variations in length proved insignificant. As a result, only changes in body weight were taken into account and analysed.

Statistics

The tests used to compare the admission data of the two groups were the χ^2 for the qualitative variables and Student's *t* test for the quantitative variables. The effect of treatment was analysed by comparing the initial means with the means observed after 7 days in hospital, first taking all children into consideration and second, considering separately those who were hospitalized for malnutrition. Children considered to be suffering from malnutrition were those with a *Z* score weight-for-age below -2 in a first analysis, or with a serum albumin concentration below 25 g/L (inferior tertile in the distribution) in a second analysis. Children with higher or equal values with regard to these thresholds were classified as not suffering from malnutrition.

The analysis of the evolution of means was carried out by applying the analysis of variance for repeated measures. Because the distribution of the weight of porridge consumed daily was asymmetrical, the median and its standard error were chosen to describe the results. To compare the daily intakes of rough matter, energy, and proteins in the two groups, the Mann-Whitney test was used, whereas to analyse the intakes over the first six days, the Friedman test was applied. The average porridge, energy, and protein intakes per kilogram body weight over the six-day period were analysed using the *t* test and two-way analysis of variance.

Results

Admission data

The two groups were comparable, with admission variables significantly different between them (table 2). However, children who were fed the high-energy-density porridge (treatment) were slightly older than those who received the traditional porridge (control), and their nutrition status was a little worse. The differences were not statistically significant (*Z* scores weight-for-age and height-for-age lower, percentage of oedema higher).

Consumption of gruels

The daily intake of gruels in the first six days of hospitalization appears in figures 1–3. On average, over the six-day period, intakes (expressed in weight of gruels) of low-energy-density porridges were significantly higher than intakes of high-energy-density porridges, 35.8 ± 3.3 (SE) versus 26.7 ± 1.7 g/kg/day ($p < .01$). But the children who were fed the high-energy-density porridges consumed significantly more energy, 29.4 ± 2.1 versus 18.9 ± 1.4 kcal/kg/day ($p < .001$), and more proteins, 1.10 ± 0.07 versus 0.75 ± 0.05 g/kg/day ($p < .001$), than those receiving the low-energy-density porridges. These differences in intakes are statistically significant for every day except for the amount (weight) of porridge consumed on days 1, 5, and 6.

The consumption of energy and protein in the two groups according to nutrition status on admission appears in table 3. The children who had low serum albumin levels on admission consumed significantly more energy and protein than those with higher levels. When these intakes are compared taking the weight-for-age *Z* score into account, children whose

TABLE 2. Admission data

Characteristics of patients	Control ($n = 74$)	Treatment ($n = 74$)	p
Mean (SD) age (mo)	9.8 (5.7)	11.6 (6.1)	0.079
No. (%) boys	55 (41)	57 (42)	NS
No. (%) breastfed children	93 (64)	83 (58)	NS
No. (%) children receiving complements to mother's milk	90 (62)	81 (57)	NS
No. (%) infections	89 (66)	91 (67)	NS
Nutrition status on admission			
mean (SD) weight (kg)	6.9 (1.5)	7.2 (1.9)	NS
mean (SD) Z score weight-for-age	−1.9 (1.3)	−2.1 (1.5)	NS
mean (SD) Z score height-for-age	−1.9 (1.4)	−2.1 (1.5)	NS
mean (SD) Z score weight-for-height	−0.7 (1.0)	−0.8 (1.9)	NS
mean (SD) arm circumference (cm)	13.1 (1.7)	13.0 (1.9)	NS
oedema % (n)	2.7 (2)	9.5 (7)	0.089
mean (SD) serum albumin concentration (g/L)	28.7 (6.1)	28.8 (8.1)	NS

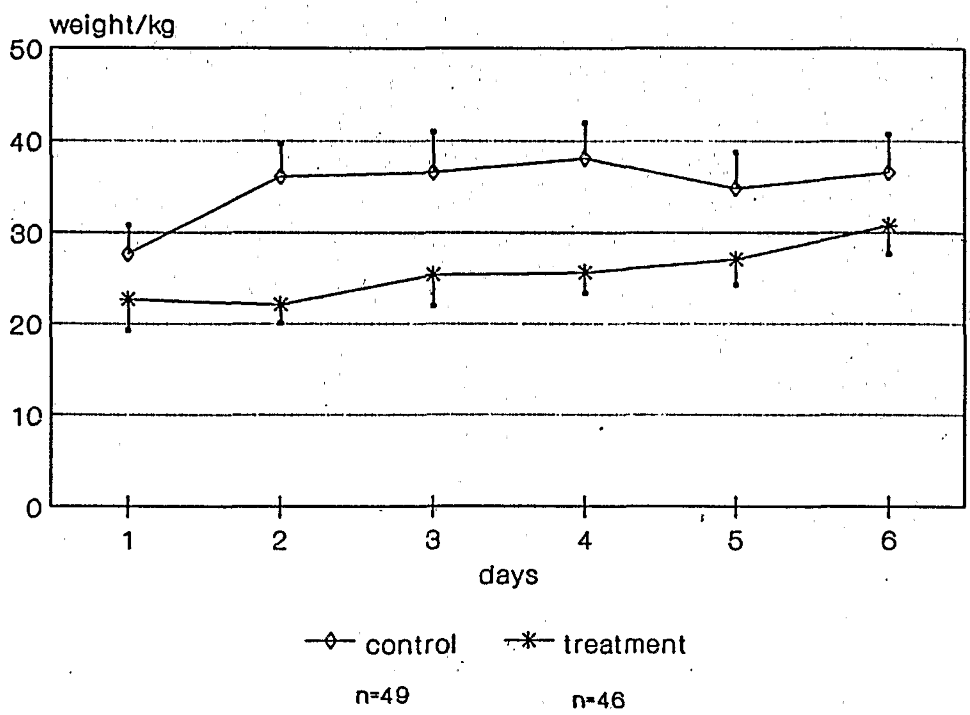

FIG. 1. Median (±SE) daily weight of gruels consumed (g/kg)

Z scores were below −2 consumed significantly more energy and protein than those whose Z scores were equal to or higher than −2. The difference between the means of intakes was more important in the treatment group and was significant only in that group.

Change of nutrition status

In the course of the study, five children (6.8%) in the control group and eight (11.0%) in the treatment group died (difference not significant). Furthermore, five children (6.8%) in the control group left the hos-

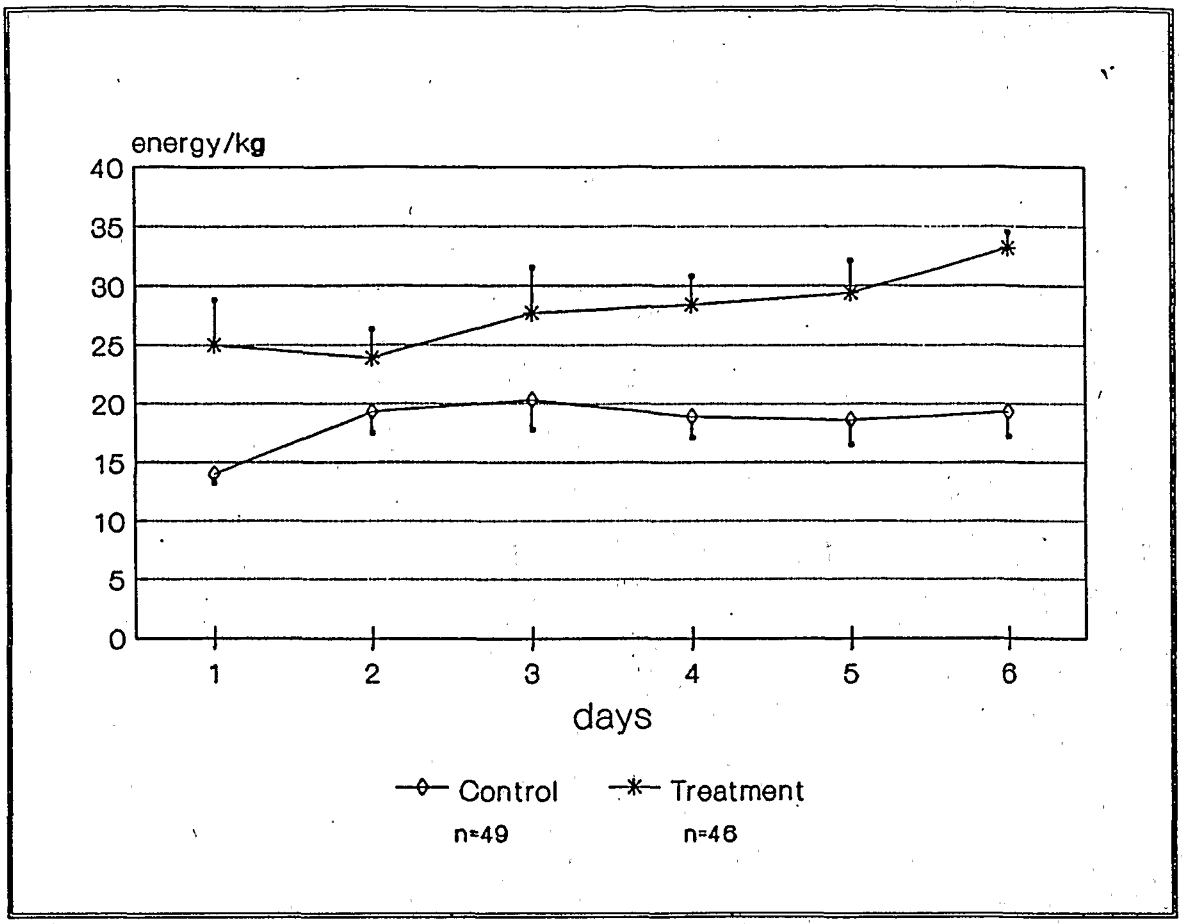

FIG. 2. Median (±SE) daily energy intake from the gruels (kcal/kg)

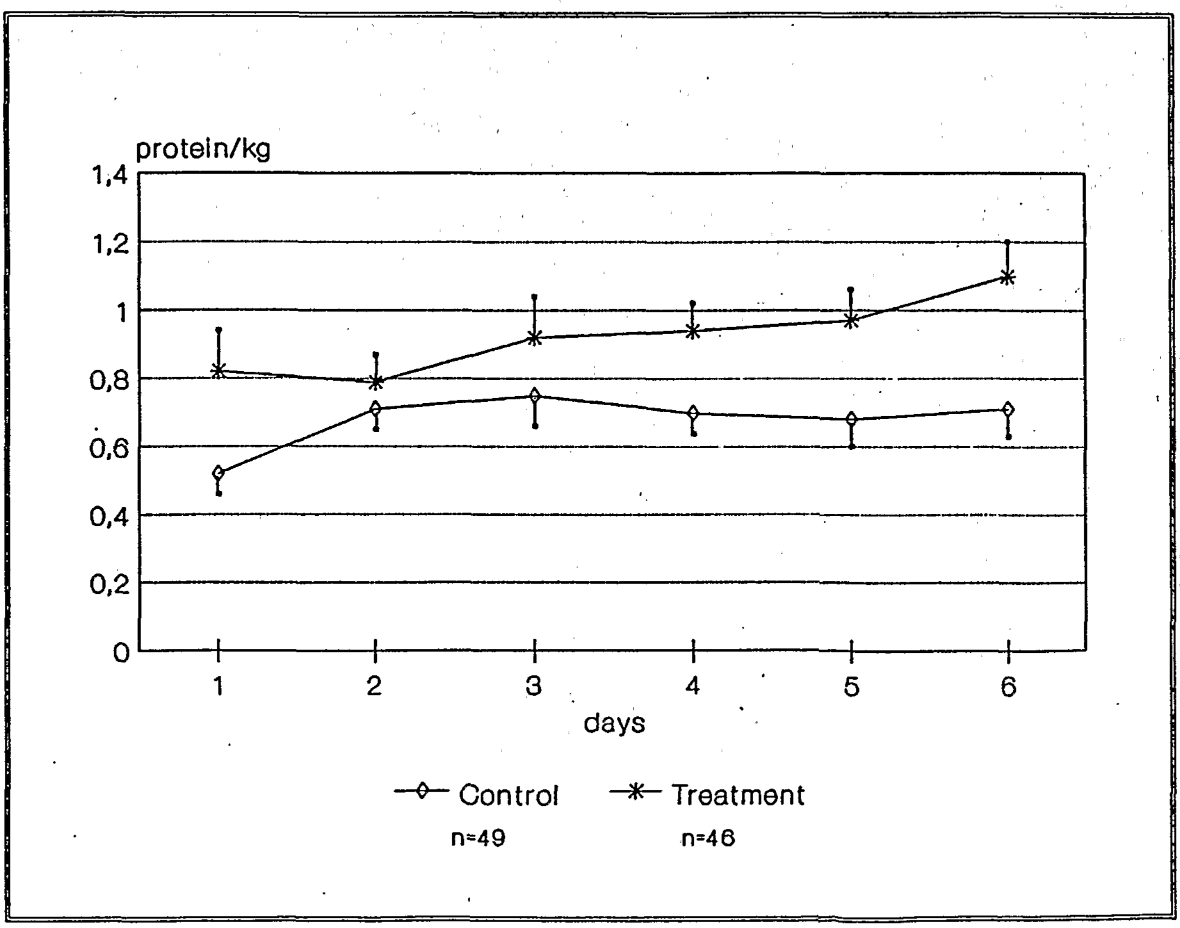

FIG. 3. Median (±SE) daily protein intake from the gruels (g/kg)

TABLE 3. Mean daily energy and protein consumption in relation to nutrition status on admission

Consumption	Albumin			
	<25 g/L		≥25 g/L	
Energy (kcal/kg)				
control	$n = 16$	24.9 (9.5)	$n = 33$	18.1 (7.3)
treatment	$n = 14$	37.1 (16.2)	$n = 32$	31.6 (15.0)
Protein (g/kg)				
control	$n = 16$	0.92 (0.35)	$n = 33$	0.67 (0.27)
treatment	$n = 14$	1.22 (0.54)	$n = 32$	1.05 (0.50)

p (groups) <.001.
p (alb) .025.
p (groups × alb) NS.

Consumption	Z score W/A			
	<−2		≥−2	
Energy (kcal/kg)				
control	$n = 19$	22.4 (9.0)	$n = 27$	19.2 (8.6)
treatment	$n = 22$	41.5 (17.3)	$n = 20$	25.8 (9.0)
Protein (g/kg)				
control	$n = 19$	0.83 (0.33)	$n = 27$	0.71 (0.32)
treatment	$n = 22$	1.37 (0.57)	$n = 20$	0.85 (0.30)

p (groups) <.001.
p (Z score W/A) <.001.
p (groups × Z score W/A) .012.

pital before the study was completed, as did four (5.5%) in the treatment group.

From admission until day 7 of hospitalization, the average weight of the children receiving low-energy-density porridge fell from 7.033 ± 1.459 to 7.028 ± 1.517 kg, whereas the average weight of the children receiving high-energy-density porridge rose from 7.307 ± 1.909 to 7.353 ± 1.891 kg. This change was not statistically significant, and there was no significant difference in the change for the two groups.

From admission until day 7 of hospitalization, the average serum albumin concentration of the children receiving the low-energy-density porridge rose from 28.6 ± 6.3 to 29.0 ± 5.9 g/L, and that of the children being fed the high-energy-density porridge rose from 29.8 ± 7.8 to 31.5 ± 5.9 g/L. This change was not globally significant ($p = .127$), nor was the difference in change for the groups significant.

The change of serum albumin concentration in relation to the nutrition status on admission is shown in figures 4 and 5. The children with a low concentration (<25 g/L) on admission showed a significant increase after seven days in hospital. The increase was comparable in the two groups. In children with a higher serum albumin concentration from the start, the rate tended to decrease in controls, whereas it remained stable in the treatment group. However, the difference in change was not significant. Figure 5 shows that for children whose weight-for-age Z score was less than −2, the albumin concentration tended to increase in the treatment group and remain stable in the control group. The difference in change between groups was not significant. In the children whose weight-for-age Z score was higher than or equal to −2, the average albumin concentration remained almost stable in both groups.

Discussion

Feeding high-energy-density porridge (1 kcal/g) to hospitalized children, most of whom suffered from malnutrition, resulted in a significant increase in energy and protein intake. On average, during the first six days of hospitalization, the quantities of energy and protein per kilogram body weight provided by the high-energy-density porridge exceeded those provided by the traditional porridge by 55.6% and 42.8%, respectively. This occurred despite the fact that the children consumed greater quantities of traditional low-energy-density porridge. Both gruels had similar viscosities, and since they were given ad libitum, it appears that it is the volume of the traditional gruel that sets a limit to the children's energy and protein intakes.

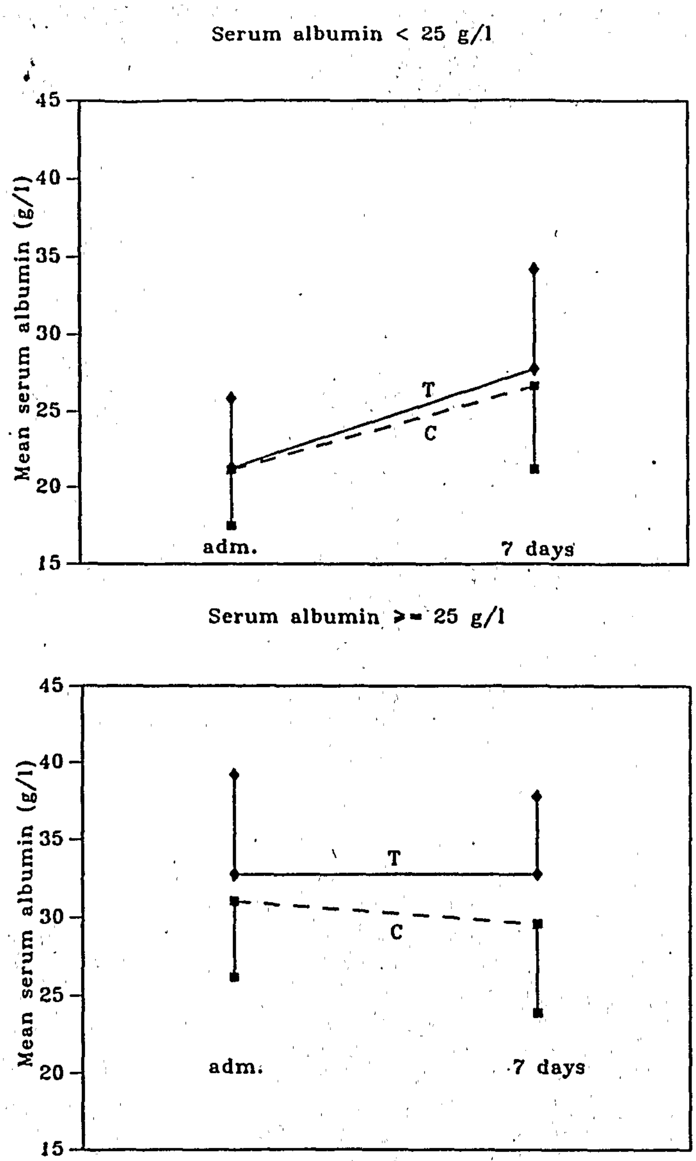

FIG. 4. Evolution of mean (±SD) serum albumin concentration between admission (adm) and 7 days in the treatment (T) and control (C) groups for children with serum albumin concentration less than 25 g/L and for children with serum albumin concentration equal to or greater than 25 g/L on admission

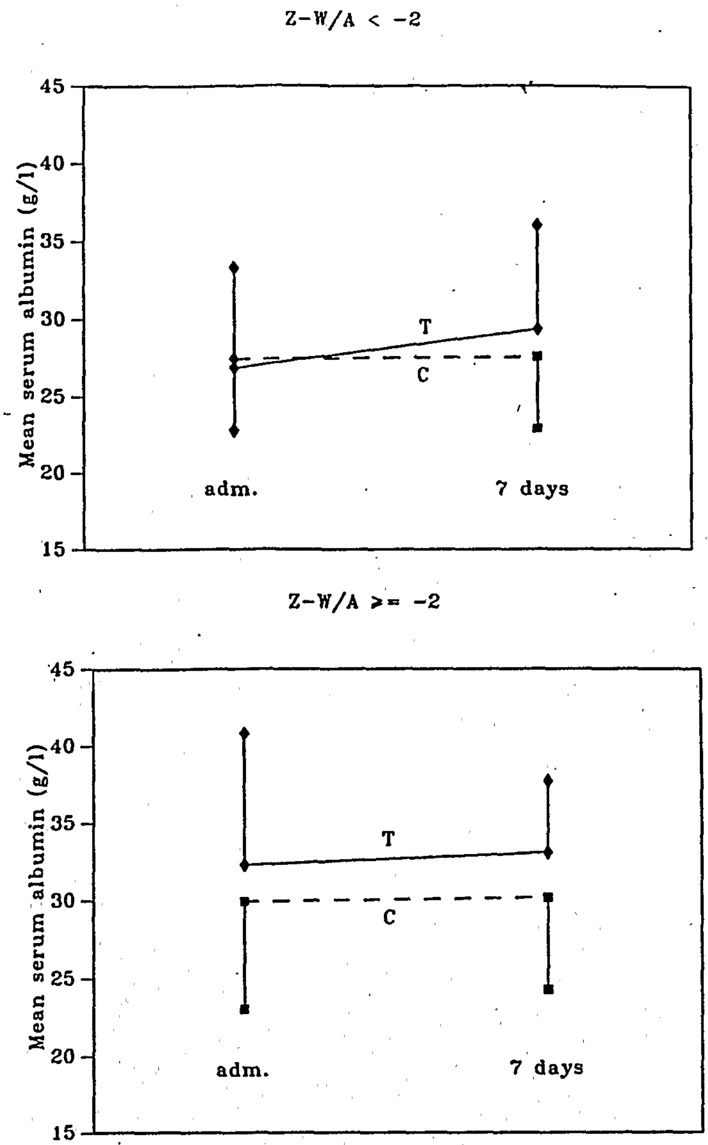

FIG. 5. Evolution of mean (±SD) serum albumin concentration between admission (adm) and 7 days in the treatment (T) and control (C) groups for children with weight-for-age *Z* score (Z-W/A) less than −2 and for children with Z-W/A equal to or greater than −2 on admission

The limited gastric capacity of young children prevents them from fulfilling their energy and protein needs with low-energy-density weaning foods. This fact was mentioned as an aetiologic factor of malnutrition in weaning children [9, 18, 19]. Our results are similar to those obtained in another intrahospital study [20]. Children receiving a high-energy-density porridge (1 kcal/g) consumed significantly more energy per day than those fed a less dense porridge (0.5 kcal/g) with equivalent viscosity. Unlike our study, they did not receive any additional food except for mother's milk. High- and low-energy-density porridges provided 148 and 110 kcal/kg/day, respectively. Those children, initially suffering from malnutrition, were taken into the study after the main complications had been treated and after they had started gaining weight. This accounts for the relatively important quantities of energy consumed. Our children also consumed significantly more energy from high-energy-density porridge (29.4 vs 18.9 kcal/kg/day), but received an additional solid intake that was not quantified. Furthermore, the study covered the first days of hospitalization, a period during which the supply should be kept lower because of the reduced metabolic rate of severely malnourished children.

A recently published study was carried out in children age 6 to 15 months who were exclusively fed porridge as a complement to mother's milk [21]. The energy consumption was 48% higher for children who received a high-energy-density porridge (97 kcal/100 g) than for those who received a less dense porridge of the same viscosity (51 kcal/100 g).

The high-energy-density porridge provides malnourished children with not only more energy but also more protein. In Kivu province, where the shortage of protein is particularly critical from October through December, it is essential that protein intake be increased. The high-energy-density porridge provides children as a whole with a 40% surplus of protein per kilogram per day. The additional intake rises to 65% with children suffering from more acute malnutrition (weight-for-age Z score < -2). Since our evaluation concerned the first days of hospitalization, children suffering from acute malnutrition are anorexic as a result of both their nutrition status and infections (nearly 90% have clinical signs of infection on admission) and presumably consume little solid food. Under such conditions, the high-energy-density porridge could be given more often than three times daily, as was the case in the present study, to fulfill energy and protein needs during this essential phase for survival.

Few data are available on the impact of these high-energy-density porridges on the nutrition status of the children. Even if studies reveal that children who consume the porridges consume greater quantities of energy and proteins, what remains to be established is whether this diet has an impact on their general health and nutrition status.

In the present study, children who received the high-energy-density porridge tended to put on more weight than those given the low-energy-density porridge. Their serum albumin concentration also tended to increase more. However, these differences were not significant. This can be explained by the short follow-up period and the fact that the porridges were only one part of the daily diet.

High-energy-density gruels were also tested outside the hospital as a possible way to prevent malnutrition. In India, infants and toddlers consumed significantly more porridge (20% wheat porridge with fat) containing amylase-rich food than children who consumed the same preparation without amylase-rich food [10]. These results were confirmed in a trial in which children who were fed the gruel containing amylase-rich food ate significantly more of the preparation than children who were given the gruel without amylase-rich food [22]. They were able to take in two to three times as many calories per sitting as those who were fed the control gruel without amylase-rich food. In Tanzania, maize and groundnut gruels were prepared in different concentrations and tested on 40 pre-school children. Children between 12 and 48 months of age consumed significantly less of the thick porridge (20% solids) than the thin (5% solids) and the liquefied porridge (20% solids with 1% germinated sorghum flour) [23].

These studies emphasize the importance of high-energy-density weaning foods, but more research should focus on the impact of these gruels on the nutrition status of the children studied. Our results show the value of these porridges in the early treatment of malnourished children, since they provide significantly more energy and proteins than traditional, less dense porridges. A better evaluation of the impact of the porridges on nutrition status would involve studying the outcome over a longer period in a group of severely malnourished children who received nothing but these gruels during the first few days of hospitalization and were then fed the porridges in addition to solid food.

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