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# Viscosity, energy density and osmolality of gruels for infants prepared from locally produced commercial flours in some developing countries

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Forty market samples of locally produced (33) and imported (7) cereal-based flours used for complementary feeding in some African countries and Vietnam were studied in order to characterise their macronutrient content and, when prepared as gruels, their viscosity, energy density, and osmolality. The results show that less than half were fairly balanced with respect to their protein and lipid content. When prepared as gruels following the manufacturers' instructions, out of the 21 locally produced flours with complete instructions, ten had energy densities too low to provide sufficient energy to complement breastmilk for 9–11-month-old infants even at three meals a day (<77 kcal or 322 kJ/100 g), nine were satisfactory if fed more than twice a day, and two if fed twice a day (>116 kcal or 485 kJ/100 g). Two of the 11 with acceptable energy density had osmolality values higher than those reported in literature for complementary feeding (<660 mOsm/kg $H_2O$). In addition, when prepared as gruels with viscosities within the range of viscosity (1 to 3 Pa.s) usually observed in African countries, 14 of the 32 (44%) locally produced flours had insufficient energy densities to meet the energy requirements of infants even at three meals a day. These results call for greater concern and effort towards improving the nutritive value and energy density of cereal-based complementary foods produced in developing countries.

## Introduction

Traditional complementary foods in developing countries are mainly semi-liquid starch-based gruels of low energy and nutrient density prepared from cereals (Svanberg, 1988; Walker & Pavitt, 1989). They often provide less energy and essential nutrients for the infant than is required to complement breast milk, thus constituting a major cause of growth faltering, malnutrition, and possible mental retardation during the weaning period (Ljungqvist *et al.*, 1981). Improving energy density by increasing the solids content often leads to high undesirable viscosity, while adding disaccharide sugars, fats and oils as is frequently recommended (UNICEF/WHO/UNESCO, 1989), may cause excessive dilution of critical nutrients, leading to other nutritional problems.

In order to allow the preparation of energy-dense gruels without increasing their viscosity too much, complex starches can be broken down so that they swell less during cooking (Hellström *et al.*, 1981). The most commonly proposed cheap method of preparing an energy-dense gruel is to add amylase-rich flour produced by germination of cereal grains to thick gruel (Desikachar, 1980; Gopaldas *et al.*, 1986; Luhila

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& Chipulu, 1988; Svanberg, 1988; Trèche, 1995). The use of low-cost extrusion cooking has also been suggested (Jansen *et al.*, 1981). But addition of disaccharide sugars and breaking down starch to glucose polymers with various chain lengths result in an increase in the osmolality of the gruels, with possible adverse consequences, such as osmotic diarrhoea, which affect the water balance of infants (Sandu *et al.*, 1982).

Until recently, in most developing countries, the only special transitional foods of good nutritional value and appropriate energy density have been imported cereal-based commercial flours with expensive ingredients, the use of which has been limited to a minority because of their high cost. The need for low-cost alternatives in these countries has given rise, in recent years, to the springing up many small and medium-size production units of commercial flours–prepared mainly from local food resources–for complementary feeding of infants (infant flours).

This study was undertaken to determine the viscosity, energy density and osmolality of gruels prepared from locally produced commercial infant flours in some African countries and Vietnam, and to find out whether their characteristics allow them to appropriately complement breastmilk to meet infant requirements.

## Materials and methods

### *Flour samples*

Market samples of 33 brands of locally produced commercial infant flours were collected in 15 African countries and Vietnam from 1991 to 1997. They included 25 brands from African countries of which 17 were produced by cottage industries and eight by semi-industrial units, and eight brands from Vietnam comprising four from cottage industries and four from semi-industrial units. To these were added seven imported brands, of which four came from African countries and three from Vietnam. The names, origins and ingredients of the flours are presented in Table 1.

### *Chemical analysis*

Proximate analysis was done on all flour samples, regardless of the composition indicated on the labels by some manufacturers, to provide a common basis for comparison. Protein (N × 6.25) was determined by Kjeldahl's method, lipids by Soxhlet extraction, fibre (ADF) by Van Soest's method, total minerals by ashing at 530°C until free of carbon, and available carbohydrates by difference (100 – protein – lipids – fibre – ash). Dry weight of flours and gruels were determined by oven-drying at 105°C to constant weight. Energy content was calculated from the proximate composition by applying the following coefficients: 4 kcal per gram of protein or available carbohydrate; 9 kcal per gram of lipids.

### *Preparation of gruels*

Four preparation procedures can be distinguished:

1. Cold-water procedure (P1): flour was mixed with cold water into a slurry and cooked by stirring over a low heat for a specified time once the mixture had started to boil.
2. Cold-boiling-water procedure (P2): flour was mixed with cold water (1 : 2 by weight) into a slurry, poured into boiling water and cooked for a specified time.
3. Boiling-water procedure (P3): flour was poured into an appropriate volume of boiling water and cooked for a specified time.
4. Instant preparation procedure (P4): flour was poured into an appropriate volume of boiled hot water (about 80°C) and stirred into a smooth gruel, without cooking.

First, gruels were prepared according to the manufacturer's instructions when available and complete (21 out of 33 locally produced flours; 5 out of 7 imported flours).

Second, 5–7 gruels of different solids concentration were prepared from each of the 40 flours to study the relation existing between viscosity, energy density and osmolality. To do this, the ratio of flour to overall volume of water was predetermined taking into consideration the required final solids concentration, prescribed cooking time, and rate of water evaporation. In the absence of manufacturer's instructions, gruels were prepared according to the P1 procedure with a cooking time of 5 minutes once the mixture had started to boil.

### *Viscosity measurement*

After preparation, gruels were cooled and maintained at 45°C in a thermostatic water-bath, and aliquots were taken for viscosity

**Table 1.** Characteristics of flours

| *Country of origin* | *Name of flour* | *Code* | *Age (mo)* | *Ingredients* | *Cooking procedure* |
|---|---|---|---|---|---|
| *Cottage industries* | | | | | |
| Benin | Ouando 1 | C-Be$_1$ | 3–6 | Corn, sorghum, rice, sugar | P2 |
| Burkina Faso | Denmugu | C-Bu$_1$ | >5 | Rice, milk, beans | P2 |
| | Kasona | C-Bu$_2$ | >4 | Millet, soybean, groundnut, sugar, salt | P2 |
| | Misola | C-Bu$_3$ | >6 | Millet, soybean, groundnut, sugar, salt | P2 |
| Burundi | Musalac | C-Bi$_1$ | >6 | Corn, sorghum, soybean, sugar, milk | P2 |
| Chad | Vitafort (millet) | C-Ch$_1$ | >4 | Millet, groundnut, cowpea | P2 |
| Congo | Harina Vitafort 2 | C-Co$_1$ | >4 | Corn, soybean, sugar, vitamin, mineral, amylase | P1 |
| | Maiso | C-Co$_2$ | >4 | Corn, soybean, sugar | P2 |
| Gabon | Nourivit | C-Ga$_1$ | >4 | Corn, milk, rice, sugar, vitamin, mineral, amylase | P1 |
| Guinea | Baraka | C-Gu$_1$ | >4 | Corn, cowpea, groudnut | P2 |
| | Yeolac | C-Gu$_2$ | >4 | Corn, sorghum, milk, soybean, sugar | P2 |
| Niger | Bitamin | C-Ni$_1$ | >6 | Millet, cowpea, groundnut | P2 |
| Rwanda | Sosoma | C-Rw$_1$ | >4 | Sorghum, soybean, corn | P2 |
| Senegal | Rhuy Xalèle | C-Se$_1$ | >4 | Millet, milk, cowpea, oil, sugar, egg, monkey-bread | P2 |
| Sierra Leone | Farine ACF | C-SI$_1$ | NS | Corn, soybean, sugar, salt, vitamin, mineral | P1 |
| Togo | Viten 1 | C-To$_1$ | 3–6 | Corn, rice, sorghum | P2 |
| | Viten 2 | C-To$_2$ | >6 | Corn, rice, soybean | P2 |
| Vietnam | NIN exp. unit | C-Vn$_1$ | >4 | Rice, glutinous rice, soybean, milk, sugar | P3 |
| | Risolac | C-Vn$_2$ | >4 | Rice, soybean, milk, mineral, amylase | P1 |
| | CPCC/Yen Bai | C-Vn$_3$ | >4 | Rice, soybean, sugar, vitamin, mineral | P3 |
| | FIRI | C-Vn$_4$ | ns | Rice, soybean, mungbean, meat, carrot, yeast, salt | P3 |
| *Semi-industrial units* | | | | | |
| Algeria | Labnamine | I-Al$_1$ | >4 | Wheat, milk, sugar, malt extract | P4 |
| Benin | Super Ouando1 | I-Be$_1$ | >3 | Corn, rice, milk, sugar | P3 |
| | Super Ouando2 | I-Be$_2$ | >6 | Corn, soybean, sorghum, sugar, vitamin, mineral | P3 |
| Burkina Faso | Vitaline | I-Bu$_1$ | >4 | Wheat, corn, sugar, groundnut, milk, mineral | P4 |
| DR Congo | Cerevap | I-Dc$_1$ | >4 | Corn, wheat, soybean, milk, oil, sugar | P4 |
| Madagascar | Farilac | I-Ma$_1$ | >4 | Wheat, milk, sugar, salt, vitamin, mineral | P4 |
| Senegal | PNC | I-Se$_1$ | NS | Millet, cowpea, groundnut, vitamin, mineral | P2 |
| | Provital | I-Se$_2$ | NS | Corn, millet, cowpea, groundnut, milk, sugar | P4 |
| Vietnam | Ridielac HV | I-Vn$_1$ | >4 | Wheat, rice, milk, egg, fat, oil, sugar | P3 |
| | Ridielac crawfish | I-Vn$_2$ | >7 | Cereal, crawfish, sugar, salt, vitamin | P3 |
| | Ridielac milk/cereal | I-Vn$_3$ | >4 | Rice, milk, sugar, salt, vitamin | P3 |
| | Ridielac meat/cereal | I-Vn$_4$ | >5 | Cereal, meat, sugar, vitamin | P3 |
| *Imported flours* | | | | | |
| France | Bledilac | IF$_1$ | >4 | Wheat, milk, defatted soybean, oil, sugar | P4 |
| Belgium | Cerelac | IF$_2$ | >4 | Wheat, milk, sugar, oil, mineral, vitamin | P4 |
| Thailand | Cerelac rice | IF$_3$ | >6 | Rice, corn, milk, vitamin, mineral | P4 |
| China | Ceresoy rice | IF$_4$ | >4 | Rice, soybean, vitamin, mineral | P4 |
| USA | CSB | IF$_5$ | NS | Corn, soybean | P2 |
| France | Nutriset | IF$_6$ | >4 | Corn, wheat, millet, sugar, soybean, milk, fat, vitamin, mineral | P4 |
| France | Phosphatine | IF$_7$ | >4 | Wheat, sugar, milk, fruit, soybean, vitamin, mineral | P4 |

NS = not specified.

measurements (at the same temperature) using a Haake VT500 viscometer: SV-Din spindle at a shear rate of 83.21 $sec^{-1}$. Readings were taken in Pascal seconds (Pa.s) after 10 minutes of spindle rotation, when they became relatively stable.

### *Osmolality measurement*

An aliquot of each gruel was centrifuged under refrigeration at 22,000–31,000 g (depending on gruel concentration) for 20 minutes, and duplicate 100 μl volume were taken for osmolality measurement using a freezing-point depression automatic micro-osmometer (Roebling type 13/13 DR).

### *Determination of energy density and osmolality values corresponding to specific viscosities*

For each flour prepared into 5–7 gruels at different solids concentration, the best-fit plots of viscosity vs energy density and of osmolality vs viscosity were made using polynomial regression equations of the experimental values. Then, energy density and osmolality values corresponding to specific viscosities (1 and 3 Pa.s) were obtained using the regression equations. These two viscosity values correspond approximately, under our measuring instrument and procedure, to the limits for drinkable (<1 Pa.s), spoonable – with a consistency of yoghurt – (>1 Pa.s and <3 Pa.s), and thick (>3 Pa.s) gruel.

## Results

### *Characteristics of flours*

The manufacturers specified the age range for which the product was intended for 34 of the 40 flours studied (Table 1). Of these, three (C-$Be_1$, C-$To_1$, I-$Be_1$) were aimed at infants below 4 months old. All the flours contained cereals (single or mixed) as the major source of carbohydrate, while soybean and/or dry powder milk constituted the principal source of protein and lipids. Groundnut and cowpea served as the main sources of protein and lipids in a few cases (C-$Ch_1$, C-$Gu_1$, C-$Ni_1$, I-$Se_1$), or in combination with soybean or milk. Vegetable oils and fats were added in several cases (C-$Se_1$, I-$Dc_1$, I-$Vn_1$, $IF_1$, $IF_2$, $IF_6$). Five of the 21 flours produced in cottage industries (type C) and 7 of the 12 from semi-industrial units (type I) were supplemented with minerals and/or vitamins, while three type C (C-$Co_1$, C-$Ga_1$, C-$Vn_2$) and one type I (I-$Al_1$) flours contained amylases.

Apart from the imported flours, only five of the locally produced flours (all of type I) were instant (I-$Al_1$, I-$Bu_1$, I-$Dc_1$, I-$Ma_1$, I-$Se_2$), requiring only that they be mixed with boiled hot water before feeding to infants. The others had to be cooked for up to 10 minutes or more after being mixed with cold, hot or boiling water. Most manufacturers' instructions followed the P2 gruel preparation procedure. The second most common was P3, and then P1 modes. The P2 preparation procedure has been reported to be quite popular in African households (Walker & Pavitt, 1989), and gives smooth gruels without lumps.

The proximate and energy composition of the flours according to our analyses are presented in Table 2. Apart from two (C-$Ga_1$, C-$To_2$), all the flours had a dry matter content higher than 90 g/100 g; the very low dry matter content of C-$To_2$ flour is probably due to bad storage conditions. The protein content (g/100 g dry weight) varied from 8.0 g in C-$Se_1$ to 17.8 g in C-$Rw_1$ for the local flours, and from 7.6 g in $IF_7$ to 18.0 g in $IF_5$ for the imported flours. For lipids, the content (g/100 g dry weight) ranged from 0.9 g in C-$Vn_4$ to 14.0 g in I-$Vn_4$ for the local flours, and from 2.3 g in $IF_7$ to 9.9 g in $IF_6$ for type IF flours. Energy values of locally produced flours (kcal or kJ/100 g dry weight) ranged from 376 kcal (1574 kJ) for I-$Al_1$ to 451 kcal (1888 kJ) for I-$Vn_4$, and were of the same order of magnitude for both type C and type I flours.

### *Viscosity, energy density and osmolality of gruels prepared according to the instructions from manufacturers*

Table 3 shows the viscosity, energy density and osmolality values of gruels prepared according to manufacturers' instructions (ratio of flour to water, mixing procedure and cooking time).

Viscosity ranged from 0.07 Pa.s for C-$Ch_1$ to 8.6 Pa.s for C-$Co_1$ (that of C-$Bu_3$ was too high to be measured), with 16 of the 26 gruels having values lower than 3 Pa.s. The energy densities (kcal or kJ/100 g) were also quite variable, ranging from 21 kcal (88 kJ) for C-$Ch_1$ to

**Table 2.** Proximate and energy composition of flours

| *Country of origin* | *Code* | *Dry matter (g/100 g flour)* | *Protein* | *Lipid* | *Ash* | *Fibre* | *Carbohydrate* | *Energy (kcal/100 g DW)* |
|---|---|---|---|---|---|---|---|---|
| | | | *g/100 g dry weight (DW)* | | | | | |
| *Cottage industries* | | | | | | | | |
| Benin | C-Be$_1$ | 92.6 | 9.9 | 3.1 | 1.3 | 4.5 | 81.2 | 392 |
| Burkina Faso | C-Bu$_1$ | 90.8 | 13.0 | 5.6 | 1.9 | 1.7 | 77.8 | 414 |
| | C-Bu$_2$ | 91.3 | 14.4 | 7.3 | 2.3 | 3.7 | 72.3 | 412 |
| | C-Bu$_3$ | 91.8 | 16.2 | 11.4 | 2.1 | 3.4 | 66.9 | 435 |
| Burundi | C-Bi$_1$ | 92.0 | 15.0 | 8.6 | 2.2 | 2.2 | 72.0 | 425 |
| Chad | C-Ch$_1$ | 93.9 | 14.1 | 7.8 | 2.1 | 4.0 | 72.0 | 414 |
| Congo | C-Co$_1$ | 90.9 | 12.1 | 6.8 | 2.7 | 3.0 | 75.4 | 412 |
| | C-Co$_2$ | 92.3 | 16.7 | 7.3 | 2.2 | 2.7 | 71.1 | 416 |
| Gabon | C-Ga$_1$ | 89.3 | 9.8 | 5.7 | 2.2 | 1.6 | 80.7 | 413 |
| Guinea | C-Gu$_1$ | 91.5 | 13.7 | 7.8 | 1.6 | 2.7 | 74.2 | 422 |
| | C-Gu$_2$ | 93.0 | 14.8 | 8.1 | 2.3 | 5.0 | 69.8 | 411 |
| Niger | C-Ni$_1$ | 95.0 | 15.7 | 9.4 | 2.0 | 5.4 | 67.5 | 417 |
| Rwanda | C-Rw$_1$ | 92.0 | 17.8 | 3.8 | 3.4 | 1.2 | 73.8 | 400 |
| Senegal | C-Se$_1$ | 94.9 | 8.0 | 5.2 | 0.7 | 0.5 | 85.6 | 421 |
| Sierra Leone | C-Sl$_1$ | 92.6 | 11.9 | 6.1 | 4.5 | 2.3 | 75.2 | 403 |
| Togo | C-To$_1$ | 92.6 | 9.0 | 3.4 | 1.2 | 4.2 | 82.2 | 395 |
| | C-To$_2$ | 82.9 | 15.5 | 7.6 | 1.8 | 4.4 | 70.7 | 413 |
| Vietnam | C-Vn$_1$ | 94.3 | 10.5 | 4.7 | 0.9 | 0.8 | 83.1 | 417 |
| | C-Vn$_2$ | 95.6 | 17.8 | 3.9 | 2.5 | 2.9 | 72.9 | 398 |
| | C-Vn$_3$ | 90.7 | 11.9 | 1.2 | 1.0 | 1.9 | 84.0 | 394 |
| | C-Vn$_4$ | 91.4 | 13.5 | 0.9 | 3.8 | 1.9 | 79.9 | 381 |
| *Semi-industrial units* | | | | | | | | |
| Algeria | I-Al$_1$ | 94.2 | 15.9 | 0.8 | 2.7 | 0.8 | 79.8 | 376 |
| Benin | I-Be$_1$ | 92.2 | 10.6 | 6.2 | 1.8 | 1.5 | 79.9 | 415 |
| | I-Be$_2$ | 91.4 | 18.8 | 4.9 | 2.2 | 3.1 | 71.0 | 403 |
| Burkina Faso | I-Bu$_1$ | 95.1 | 12.7 | 9.5 | 1.5 | 1.4 | 74.9 | 436 |
| DR Congo | I-Dc$_1$ | 92.0 | 15.4 | 6.5 | 2,8 | 3.3 | 72.0 | 408 |
| Madagascar | I-Ma$_1$ | 98.5 | 13.3 | 7.5 | 2.2 | 0.2 | 76.8 | 428 |
| Senegal | I-Se$_1$ | 93.5 | 15.1 | 8.5 | 1.6 | 2.2 | 72.6 | 427 |
| | I-Se$_2$ | 94.3 | 9.6 | 7.4 | 2.0 | 2.3 | 78.7 | 417 |
| Vietnam | I-Vn$_1$ | 93.6 | 11.9 | 5.2 | 2.2 | 0.2 | 80.5 | 416 |
| | I-Vn$_2$ | 94.4 | 13.5 | 12.7 | 4.3 | 1.1 | 68.4 | 442 |
| | I-Vn$_3$ | 96.1 | 9.2 | 8.2 | 2.1 | 0.6 | 79.9 | 430 |
| | I-Vn$_4$ | 93.3 | 13.5 | 14.0 | 4.3 | 0.5 | 67.9 | 451 |
| *Imported flours* | | | | | | | | |
| France | IF$_1$ | 92.9 | 14.7 | 6.4 | 3.2 | 0.9 | 74.8 | 416 |
| Belgium | IF$_2$ | 92.3 | 16.2 | 8.4 | 2.5 | 1.7 | 71.2 | 425 |
| Thailand | IF$_3$ | 92.6 | 15.5 | 9.0 | 3.5 | 1.9 | 70.1 | 423 |
| China | IF$_4$ | 94.0 | 15.4 | 9.2 | 3.8 | 1.2 | 70.4 | 426 |
| USA | IF$_5$ | 91.3 | 18.0 | 6.8 | 3.5 | 2.5 | 69.2 | 411 |
| France | IF$_6$ | 93.3 | 13.3 | 9.9 | 3.0 | 1.3 | 72.5 | 432 |
| France | IF$_7$ | 91.8 | 7.6 | 2.3 | 0.5 | 1.6 | 88.0 | 403 |

143 kcal (599 kJ) for C-Ga$_1$. The very low energy density and viscosity obtained for C-Ch$_1$ probably resulted from faulty instructions/printing errors.

Osmolality (mOsm/kg $H_2O$) ranged from 38 to 700 for type C gruels and from 142 to 671 for type I gruels, and was about 350 for type IF gruels.

### *Energy density and osmolality of gruels prepared at specific viscosities*

Figure 1 shows typical plots of viscosity vs energy density obtained after preparing gruels at different solids concentration. For the remaining 35 plots, three were situated to the left of C-To$_1$, ten between the latter and C-Bi$_1$, eight between C-Bi$_1$ and I-Vn$_1$, and 11 between

**Table 3.** Viscosity, energy density and osmolality of gruels prepared according to manufacturers' instructions

| *Country of origin* | *Name of flour* | *Code* | *Viscosity (Pa.s)* | *Energy density (kcal/100 g)* | *Osmolality (mOsm/kg $H_2O$)* |
|---|---|---|---|---|---|
| *Cottage industries* | | | | | |
| Burkina Faso | Misola | C-Bu$_3$ | Over range | 99 | 204 |
| Chad | Vitafort mil | C-Ch$_1$ | 0.07 | 21 | 38 |
| Congo | Harina Vitafort 2 | C-Co$_1$ | 8.68 | 138 | 365 |
| | Maiso | C-Co$_2$ | 2.38 | 59 | 61 |
| Gabon | Nourivit | C-Ga$_1$ | 3.55 | 143 | 700 |
| Guinea | Yeolac | C-Gu$_2$ | 0.46 | 50 | 150 |
| Niger | Bitamin | C-Ni$_1$ | 1.79 | 60 | 77 |
| Rwanda | Sosoma | C-Rw$_1$ | 0.69 | 58 | 124 |
| Vietnam | CPCC/Yen Bai | C-Vn$_3$ | 0.83 | 72 | 139 |
| | FIRI | C-Vn$_4$ | 2.01 | 72 | 275 |
| *Semi-industrial units* | | | | | |
| Algeria | Labnamine | I-Al$_1$ | 1.35 | 60 | 260 |
| Benin | Super Ouandol | I-Be$_1$ | 2.78 | 70 | 168 |
| | Super Ouando2 | I-Be$_2$ | 5.66 | 78 | 142 |
| DR Congo | Cerevap | I-Dc$_1$ | 3.51 | 115 | 398 |
| Madagascar | Farilac | I-Ma$_1$ | 2.03 | 99 | 465 |
| Senegal | PNC | I-Se$_1$ | 4.19 | 73 | 170 |
| | Provital | I-Se$_2$ | 0.78 | 91 | 398 |
| Vietnam | Ridielac HV | I-Vn$_1$ | 5.01 | 93 | 441 |
| | Ridielac crawfish | I-Vn$_2$ | 3.30 | 84 | 671 |
| | Ridielac milk/cereal | I-Vn$_3$ | 2.54 | 84 | 434 |
| | Ridielac meat/cereal | I-Vn$_4$ | 5.14 | 85 | 386 |
| *Imported flours* | | | | | |
| France | Bledilac | IF$_1$ | 0.24 | 72 | 326 |
| Belgium | Cerelac | IF$_2$ | 1.29 | 100 | ND |
| Thailand | Cerelac rice | IF$_3$ | 0.79 | 83 | 349 |
| France | Nutriset | IF$_6$ | 3.83 | 112 | 353 |
| France | Phosphatine | IF$_7$ | 1.01 | 90 | ND |

ND = not determined.

I-Vn$_1$ and IF$_2$. Plots for three gruels (I-Se$_2$, IF$_1$ and IF$_4$) fell well to the right of IF$_2$.

Figure 2 presents the energy density values of gruels between 1 and 3 Pa.s. The energy density (kcal or kJ/100 g of gruel) of the locally manufactured products varied from 39–97 kcal (163–406 kJ) and 56–129 kcal (234–540 kJ) at 1 and 3 Pa.s, respectively, with C-Co$_2$ having the lowest values and I-Se$_2$ the highest values. Values for type IF gruels ranged from 77–119 kcal (322–498 kJ) at 1 Pa.s and 105–156 kcal (440–653 kJ) at 3 Pa.s for IF$_7$ and IF$_4$ respectively, with the exception of values for IF$_5$ which is not an infant flour *per se*, but which is often used as such. At both viscosities, energy densities were similar for type C and type I gruels, but lower (by about one-third) than those for type IF gruels.

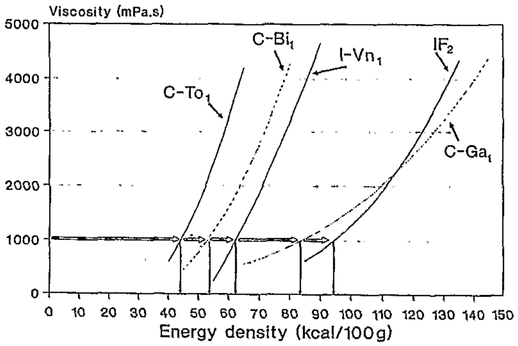

**Figure 1.** Typical viscosity vs energy density plots for some of the gruels under study.

Osmolality of gruels at solids concentration corresponding to viscosity of 1 and 3 Pa.s are presented in Figure 3. Osmolality (mOsm/kg $H_2O$) for gruels from local flours varied from 24–439 and 36–990 at 1 and 3 Pa.s respectively, while values for gruels from type IF

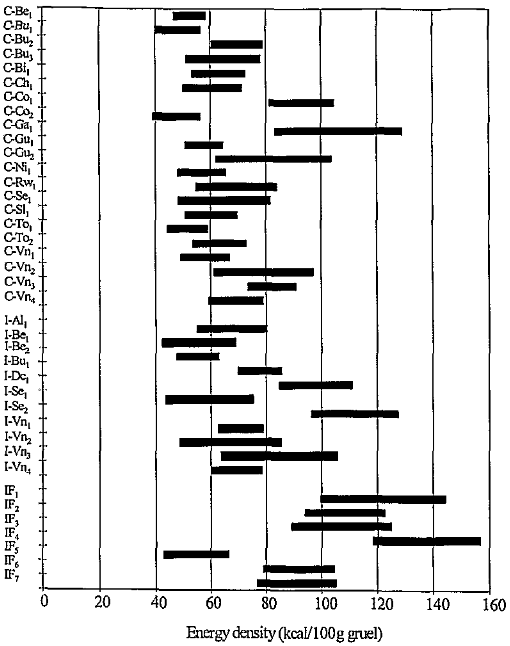

**Figure 2.** Energy density of gruels for viscosities between 1 and 3 Pa.s.

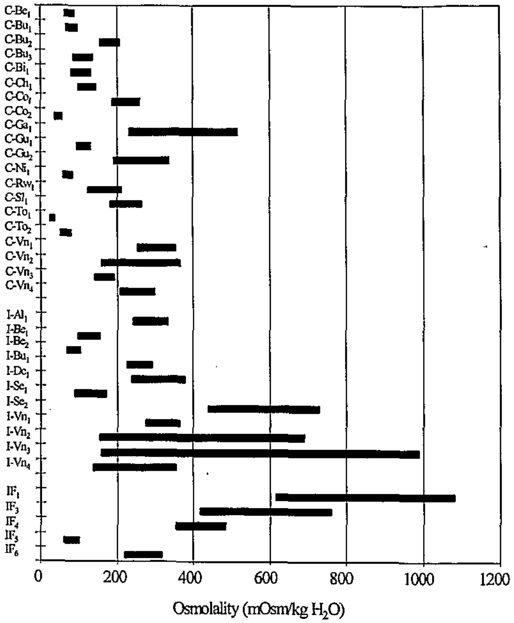

**Figure 3.** Osmolality of gruels for viscosities between 1 and 3 Pa.s.

flours ranged from 43–119 and 102–1080 at the same viscosities.

## Discussion

From the above, it can be seen that the 40 flours studied have very different energy and nutrient contents due to the types and proportions of ingredients used. According to current recommendations, a complementary food should contain at least 15 g of protein per 100 g dry weight (FAO/OMS Codex, 1994) and as much as 21% of energy as fat (WHO, 1998). The proportion of flours with adequate protein content was higher for the imported flours (5 out of 7) than for type C flours (7 out of 21) and type I flours (4 out of 12). The percentage of energy as fat was above the recommended level for only three locally produced flours (C-$Bu_3$, I-$Vn_2$, I-$Vn_4$) and for none of the imported flours. In addition, two type C (C-$Vn_2$, C-$Vn_4$), one type I (I-$Al_1$) and one type IF ($IF_7$) flours had very low lipid content.

The viscosity of gruels traditionally consumed in developing countries is not well documented because of measurement difficulties in free-living conditions. However, Mosha *et al.* (1983), using the Haake Rotovisco, found that viscosities of gruels fed to children (unspecified age) ranged from 1 to 3 Pa.s. Average viscosities of traditional gruels given to 4–11-month-old Congolese infants, determined using the same measuring instrument and procedure as indicated for the present study, ranged from 0.5 to 2.8 Pa.s according to their age (Trèche, 1995). Nout (1993) has proposed that infant gruels must have an easy-to-swallow semi-liquid consistency ranging from 1 to 3 Pa.s. Out of the 21 local flours prepared into gruels according to manufacturer's instructions, five had a viscosity below 1 Pa.s, seven had a viscosity ranging from 1 to 3 Pa.s, four had a thick, easily heaped on a spoon viscosity (3 to 4.5 Pa.s), and five had a solid consistency (>4.5 Pa.s) which can be considered as unsuitable for 6–11-month-old infants in most contexts, particularly in Africa. As for the five gruels prepared from imported flours, four of them had a viscosity below 1.5 Pa.s and one had a thick consistency (3.8 Pa.s) indicating that most of the exporting manufacturers consider that a low or moderate viscosity is generally expected by consumers.

The energy densities of gruels prepared from locally produced flours following manufacturer's instructions were higher, except for one flour (C-$Ch_1$), than values reported for typical infant gruels in developing countries (25–50 kcal/100 g or 105–209 kJ/100 g) by Pavitt (1987), Brown (1991) and Ashworth and Draper (1992), but were less than 80 kcal or 335 kJ per 100 grams for the majority (11 out of 21). Minimum energy densities of complementary foods have recently been estimated, taking into account age and gastric capacity of infants and the number of meals per day and quantity of breast milk consumed (WHO, 1998). These estimations indicate that gruels should have minimum energy densities of 77 and 116 kcal (322 and 485 kJ) per 100 g in order to meet the energy requirements of well-nourished infants of 9–11 months with average breastmilk intakes, receiving, respectively, three and two meals a day. These minimum energy densities are lower for 6–8-month-old infants (88 and 59 kcal or 368 and 247 kJ per 100 g, respectively) but are higher for infants with low breastmilk intakes, for growth-retarded infants and for 12–23-month-old children. Considering that a gruel prepared from a commercial flour must at least have a sufficient energy density for well-nourished infants throughout the 6–11-month age range, 77 and 116 kcal (322 and 485 kJ) per 100 g can be considered as key values for defining the potential of gruels for fulfilling infant energy requirements in complement of breastmilk. These key values permit classifying the gruels studied into three groups: gruels with less than 77 kcal or 322 kJ/100 g having energy densities too low to provide sufficient energy to the breastfed infant even at three meals a day (group I); those with 77–116 kcal or 322–485 kJ/100 g which could do so if fed more than twice a day (group II); and those with more than 116 kcal or 485 kJ/100 g which would suffice if fed only two meals a day (group III). Of the 21 locally produced infant flours prepared according to the manufacturer's instructions, only two belonged to group III, nine to group II and ten to group I. All gruels from imported flours, except $IF_1$, fell in group II. However, because the instructions from the manufacturers are often incomplete or unavailable (12 out of the 33 locally produced flours studied) or for other reasons (e.g. illiteracy, habit of preparing gruel at lower consistency, willingness to save flours, etc.), mothers often prepare gruels without following manufacturers' instructions. Thus, energy density of gruels also have to be examined when they are prepared at solids concentration, corresponding to the viscosity value (3 Pa.s) above which gruels are generally regarded as thick. When classified according to their energy density corresponding to this viscosity value, 14 of the 32 (about 44%) gruels prepared from the locally produced infant flours fell in group I, 16 (50%) in group II and only two (about 6%) in group III while only one ($IF_5$) gruel prepared from the seven imported flours belonged to group I. It may be remarked that, of the three local flours allowing the preparation of gruels belonging to group III, either following instructions from manufacturers or at a viscosity of 3 Pa.s, two contained amylase and the other was produced by extrusion cooking.

Little is known about osmolality values of traditional gruels. The values reported by Tomarelli (1976) for milks and infant formulas ranged from 225 to 660 mOsm/kg $H_2O$. Gruels used in a controlled trial with young children during convalescence from diarrhoea by Rahman *et al.* (1994) varied between 387 and 599 mOsm/kg $H_2O$. Nine out of 21 gruels prepared following manufacturer's instructions had osmolality below this range (<200 mOsm/kg $H_2O$) while two (C-$Ga_1$ and I-$Vn_2$) had osmolality values of over 600 mOsm/kg $H_2O$. When prepared as gruels at solids concentration corresponding to a viscosity of 3 Pa.s, three of the 32 locally produced flours and two of the five imported had osmolality values exceeding 700 mOsm/kg $H_2O$. The excessive osmolalities of gruels prepared from these five flours (I-$Se_2$, I-$Vn_2$, I-$Vn_3$, $IF_1$, and $IF_3$) are probably due to significant sucrose incorporation (generally not specified but reaching 25 g/100 g of flour in I-$Vn_3$) and/or result from starch disruption into dextrins during extrusion-cooking. Note that, for the same flours, osmolality of gruels is almost proportional to their solids concentration, and hence energy density, whereas this may not be the case for gruels from different flours. This could reflect variations in the type and concentration of ionic particles and/or the carbohydrate chain lengths of the gruels.

In conclusion, many of the locally produced flours did not have the potential for use as special transitional foods. When prepared as gruels, nearly 50% of them had energy densities that were too low to meet the energy requirements of infants even at three meals a day, while a few had high osmolality. Amongst the imported flours, we should point out that CSB ($IF_5$), if not appropriately processed, does not permit the preparation of a gruel with sufficient energy density at an acceptable viscosity for 6–11-month-old infants. Much still needs to be done in terms of improving the nutrient content of the gruels using more appropriate ingredients in the right proportions and adapting technologies for reducing their high viscosity and increasing their energy density.

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