COMPLEMENTARY FOODS IN DEVELOPING COUNTRIES: IMPORTANCE, REQUIRED CHARACTERISTICS, CONSTRAINTS AND POTENTIAL STRATEGIES FOR IMPROVEMENT

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Introduction

In most contexts of developing countries, malnutrition and growth failure appear at the age of about 6 months and prevalence of stunting reaches a maximum before 24 months of age *(1)*. This coincides with the weaning period, which is the time period when different kinds of foods are successively introduced to complement breastmilk.

In regard to the simultaneity of the apparition of protein energy malnutrition and of the introduction of complementary foods, it appears that there are probably strong relationships between malnutrition and complementary foods. They can be either directly related because inadequate complementary food intakes or nutritional value leads to insufficient energy or micronutrient absorption or indirectly related since the early introduction of complementary foods often reduces breastmilk intakes and can cause food borne diseases (i.e., diarrhoea, parasitic infections) *(2)* or reduce the micronutrient bio-availability of the whole diet.

Complementary foods can de defined as any liquid or solid nutrient-containing foods given to young children in addition to breastmilk *(1)*. In most contexts of developing countries, the first complementary foods consist in special transitional foods like gruels generally prepared from blends of flours or from fermented cereal doughs. As total energy and nutrient intakes of infant is the sum of energy and nutrient intakes from breastmilk and from complementary foods, the adequacy of the characteristics of these special transitional foods to the nutritional requirements and physiological or anatomical constraints of infants appears to be one of the necessary conditions of sufficient dietary intake, therefore of normal growth.

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Factors affecting energy and nutrient intakes from complementary foods

The variability and low level of energy intakes from complementary foods can be illustrated by giving some results of 11 surveys (Trèche et al, unpublished) recently carried out in five African countries (Burkina Faso, Cameroon, Congo, Guinea and Senegal) on 4-to-23-month-old children (Table 1). One of the objectives of these surveys was to estimate the amounts of complementary foods, which are effectively consumed per meal in free-living conditions.

Table 1: Gruel intakes of infants and young children in free-living conditions in five African countries.

Countries (setting)	*Age* (month)	*Type of gruels*	*n*	*Amount consumed* g/meal	g/meal/Kg
Burkina Faso (Rural area)	4-23	Home made	34	98	13.0
Burkina Faso (Urban district)	6-8	Locally processed blend	139	74	10.9
	6-8	Local infant flours	180	46	6.2
	6-23	Fermented millet	24	128	13.7
Cameroon (Urban district)	4-11	Fermented maize	60	99	12.7
		Imported infant flour	50	98	15.1
Congo (Urban district)	6	Fermented maize	252	141	20.6
		Locally processed blend	73	135	19.0
		Imported infant flour	64	109	15.4
Guinea (Urban district)	6-11	Locally processed blend	108	135	15.5
Senegal (Urban districts)	6-35	Locally processed blend	203	95	10.6
Average					15.3

n: number of observed meals Source: Trèche et al, unpublished

The average amount of gruel consumed ranged from 46 to 141 g per meal corresponding to only about 6 to 21 g per meal and per kg of body weight with a general average of about 15 g per meal and per kg of body weight. This value is considerably lower, about half, than the generally recognized gastric capacity, which is about 30 g per kg of body weight *(3)*. Therefore, young children do not consume the quantity of transitional foods that they could normally do. This leads to take a special interest in the determining factors of their food intakes in order to understand their low level and important variability.

Amongst the determining factors of energy and nutrient intakes from complementary foods, one can distinguish between:

- Immediate factors;
- Underlying factors which can be categorized as food, caregiver and child dependent;
- Some more basic causes related to household and mother characteristics, to food availability and to child's characteristics *(4,5)*.

Three immediate factors determine the level of the daily energy or nutrient intakes from complementary foods: the number of meals per day, the amount of complementary foods consumed at each meal and the energy or nutrient density of each meal. Thus, the total energy intake from complementary foods can be calculated using the following formula *(5)*:

$$EI_d = \sum_{i=1}^{n} = Ca_i \text{ x } ED_i$$

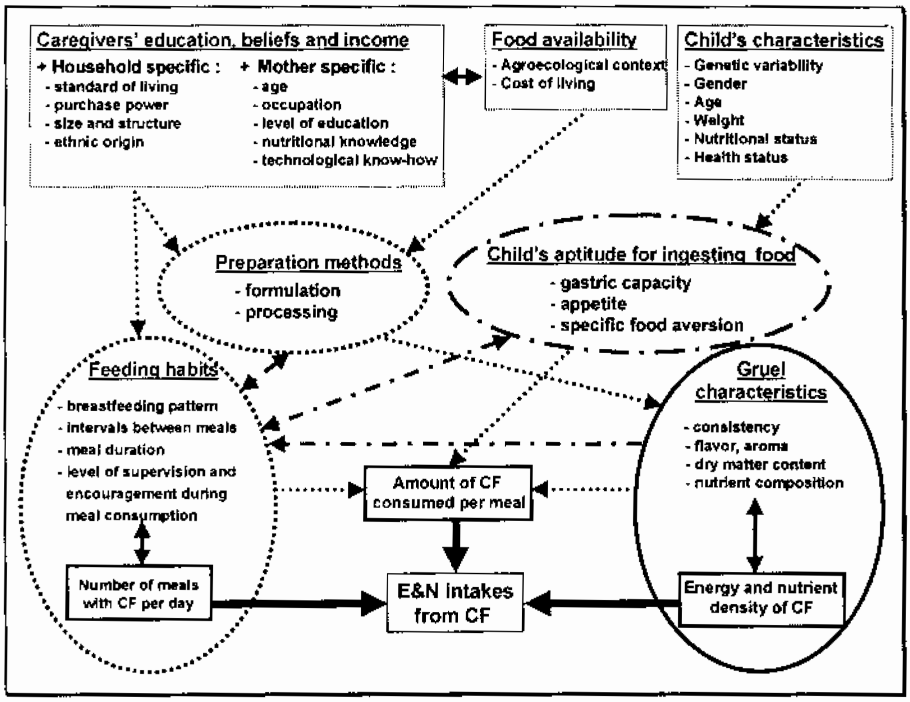
with:

- EId = Daily energy intake (kcal/d) from complementary foods
- i = Rank of the meal
- n = Total number of meals
- Ca_i = Consumed amount (g) of the i^{th} meal
- ED_i = Energy and nutrient density (kcal/g) of the i^{th} meal

In developing countries, the number of meals per day generally does not exceed two or three and cannot be easily increased because of the heavy workload of mothers. Energy density mainly depends on the nature of foods and processes used for preparing meals. The amounts consumed per meal depend on numerous underlying factors.

These underlying factors and their relationships with other determining factors can be summarized on a conceptual framework of determinants of daily energy and nutrient intakes from complementary foods (Figure 1).

Figure 1: Conceptual framework of determinants of daily energy and nutrient intakes from complementary foods (CF)



Amongst the underlying factors, a distinction can be made between those relative to the complementary foods, those relative to caregivers and those related to the child.

The complementary food characteristics likely to influence intakes mainly consists in consistency, other organoleptic characteristics such as flavour and aroma *(6)*, and dry matter and nutrient content which directly determine energy and nutrient density of the gruel, but can also influence its appetibility *(7)*. Particularly, the importance of energy density and consistency of gruels on gruel intakes have been demonstrated *(8-10)*.

Caregivers' dependent factors can be subdivided into those, which determine the methods of preparing gruels and those corresponding to feeding habits. In addition to the daily feeding frequency, these include breast-feeding patterns, intervals between meals, meal duration and level of supervision and encouragement provided during meal consumption.

The third category of underlying factors corresponds to child aptitude for ingesting foods, which mainly includes gastric capacity and appetite.

Three kinds of basic causes can be considered: caregivers' education, beliefs and income, food availability and child's characteristics. The first one includes household characteristics (i.e., standard of living, purchasing power, size and structure of the household, ethnic origin of household members) and mother's characteristics (i.e., age, occupation, level of education, nutritional knowledge, technological know). The second one corresponds to food availability and depends on the agro-ecological context and, when foods are not produced by the mother, on the price of ingredients likely to be incorporated into the gruels. The third one corresponds to child's characteristics, both permanent like genetic factors or gender, and temporary like age, weight, nutritional and health status.

The relative significance of the various immediate and underlying factors in free-living conditions is still not well known and probably depends on the context *(4,5)*.

Required characteristics

Taking into account their role and factors likely to determine their level of intakes, it is easy to define the main general required characteristics of complementary foods, particularly those of special transitional foods:

- They must not reduce breastmilk intake and, as far as possible, the bio-availability of micronutrients contained in breastmilk;
- They must be safe that is to say free of pathogens and toxic compounds;
- They must have an appropriate energy and nutrient contents with sufficient bio-availability;
- They have to be accessible and acceptable.

The necessary safety of complementary foods has been extensively emphasized *(2)* and begins to be well known. But their required nutritional characteristics and the conditions of their accessibility and acceptability are still often not well known and deserve to be reminded.

Characteristics relative to the nutritional value of special transitional foods

The principle for calculating the desired average energy or nutrient density of complementary foods consists in calculating the amount of energy or nutrient needed from complementary foods by subtracting the amount of energy or nutrient consumed from breastmilk from total energy or nutrient requirements of the child *(1)*. Then the desired average energy or nutrient density in complementary foods is obtained by dividing the amount energy or nutrients needed from complementary foods by the total amount of complementary foods which is daily consumed.

This calculation is the first step of the estimation of the minimum energy density required for complementary foods (Table 2).

Table 2: Estimation of the minimum energy density of complementary foods (kcal/100g)

Class of age	*Requirement (kcal/d)*		*Energy intake from breastmilk (kcal/d)*	*Energy that a child must be able to consume from CF (kcal/d)*	*Gastric capacity*[3] *(ml)*	*Minimum energy density depending on the number of meals per day*		
	Average[1]	+2SD				2 m/d	3 m/d	4 m/d
6-8 month	682	852	Low[2]: 217	635	249	128	85	64
			Average: 413	439		88	59	44
9-11 month	830	1037	Low[2]: 157	880	285	155	103	77
			Average: 379	658		116	77	58
12-23 month	1092	1365	Low[2]: 90	1275	345	185	123	92
			Average: 346	1019		148	98	74

[1] From Butte *(11)* and Torun et al *(12)*

[2] Mean-2SD of energy intakes observed in developing countries

[3] Taking into account an average gastric capacity of 30 ml per kg of body weigh

For each class of age, after estimating a safe level of energy requirement by adding two standard deviations to the average requirement of children, the estimated energy of breastmilk is subtracted taking into consideration average or low level of breastmilk intakes to obtain the energy that a child must be able to consume from complementary foods. After taking into account gastric capacity, it is possible to calculate the minimum energy density corresponding to different feeding frequencies. If children consume two meals per day, which is the most prevalent feeding frequency in developing countries, a minimum energy density of 128 kcal per 100 g is necessary to allow most children between 6 and 9 months of age to meet their energy requirement. This energy density is also sufficient to meet the energy requirements of older children with three meals per day and low breastmilk intakes. Thus, an energy density of about 120 kcal per 100 g can be considered as a reasonable value for most children less than 2 year old.

The same calculation can be used to estimate the desired mineral and vitamin density of complementary foods by class of age and by level of breastmilk intake taking into account different levels of bio-availability *(1)*. The desired values are generally expressed per 100 kcal. Thus, if the complementary foods have micronutrient contents at least equal to these values, the corresponding mineral or vitamin requirements will be met if children consumed sufficient amounts of complementary foods to meet their energy requirement.

But micronutrients must not only be available but also bio-available that is to say effectively absorbed and metabolized *(13,14)*. Bio-availability depends on:

- The chemical nature of nutrients;
- The physicochemical environment of molecules;
- The technological processes applied;
- The ability of the digestive tract of young children to adapt to different nutritional and physiopathological situations;
- The absence of anti-nutritional factors.

The most frequently encountered anti-nutritional factors are phytates which limit the bio-availability of protein, phosphorus and, above all, bivalent cations (e.g., Iron, Zinc and Calcium), enzyme inhibitors like antitrypsic factor which reduces the hydrolysis of proteins, polyphenols or tannins which can reduce protein digestibility and mineral bio-availability, lectins which can decrease digestive capacity and absorption and cause gastro-intestinal disorders and alpha-galactosides which cause flatulence and diarrhoea. Appropriate technological processes, mainly biological or thermic, must be used during complementary food preparation in order to reduce the activities of these anti-nutritional factors *(14, 15)*.

Accessibility and acceptability

Concerning accessibility and acceptability; required characteristics depend on whether complementary foods are bought or homemade by caregivers.

For commercial products, in order to effectively contribute to child feeding, complementary foods and particularly special transitional foods, have to:

- Be available close to households with young children;
- Be cheap because of the low purchase power of most households;

- Be free of ingredients corresponding to food taboos;
- Be easy to prepare because of the heavy workload of mothers which often limits the time devoted to preparation and distribution of meals;
- Have organoleptic characteristics corresponding to local food preferences.

For homemade complementary foods, there are two main conditions: appropriate ingredients must be available and caregivers must have time and sufficient technological and nutritional knowledge.

Present situation of food products used as special transitional foods in developing countries

Commercialized food products usually used as special transitional foods in developing countries are mainly fermented products and infant flours.

Fermented products

These products which are commonly used for preparing gruels in African countries have numerous advantages because lactic fermentation induces favourable modification of nutrient composition, improves protein digestibility, reduces activity of some antinutritional factors such as phytates, tannins, and α-galactosides, inhibits pathogen growth and toxin production and confers to final products appreciated organoleptic characteristics in general *(16)*.

But they present also risks and disadvantages linked to the fact that:

- Traditional fermentation induces insufficient reduction of viscosity which does not allow the preparation of gruels having both appropriate energy density and consistency;
- Fermented gruels have generally insufficient essential nutrient density because they are generally prepared from only cereal and sugar;
- The amount of the D form of lactic acid produced can result in acidosis;
- Some pathogenic organisms, food borne viruses, mycotoxins and bacterial toxins can be resistant to the environmental changes induced by fermentation.

Commercial infant flours

These products found on the market in developing countries are likely to present several flaws. Their hygienic quality depends on the quality of raw materials and hygienic practices during processing. Their energy density is generally insufficient unless gruels are prepared using appropriate processes or when sources of amylases are added. Their nutrient content is generally insufficient for lipids and minerals and vitamins unless supplements are incorporated. Last, but not least, their price is out of reach of the majority of households.

The insufficiency of energy density of gruels prepared from most of the commercial flours locally produced in developing countries has been illustrated *(17)* by calculating the energy density of gruels prepared from different kinds of flours at concentrations corresponding to acceptable viscosity for infants. Amongst gruels prepared from 21 blends produced in small-scale production units only one from Gabon in which amylases were incorporated allowed to prepare gruels with both a sufficient energy density and an appropriate consistency. The situation was the same for infant flours locally produced in semi-industrialized production units as only 1 out of 11 blends, produced by extrusion cooking in Senegal, presented the required energy density and consistency. The situation was better, but still insufficient, for blends produced and commercialized in developing countries by the international industry. Thus, energy density of gruels prepared from commercialized infant flours produced in numerous developing countries appears to be insufficient except for the few flours produced following appropriate technological processes.

The determination of nutrient contents of infant flours locally produced in Africa and which were randomly collected in various African countries (Table 3) show that, with the exception of protein, nutrient contents are generally inferior to the required nutrient or micronutrient contents for most of the analyzed infant flours *(18)*.

Potential technological ways to improve complementary foods

Improvements are needed at different levels: hygienic quality, energy density, nutrient balance and nutrient bio-availability. Improving energy density of gruel is of particular importance because, if its nutrient/energy ratio is well balanced, its nutrient density is improved at the same time.

Table 3: Nutrient content of some infant flours from local production units in Africa

Country	*Flour name*	*Protein (g/100g DM)*	*Lipids (g/100g DM)*	*Calcium (mg/100 gDM)*	*Iron (mg/100g DM)*
Benin	Ouando 2nd age	22.5	6.4	102	9.4
Burkina Faso	Misola	16.2	11.4	96	5.2
	Vitaline	12.7	9.5	128	6.7
Burundi	Musalac	15.0	8.6	79	12.9
Chad	Vitafort	11 to 15	4.6 to 7.8	20 to 28	2.3 à 7.0
Congo	Harina forte	12.1	6.8	325	8.6
Côte d'Ivoire	Farinor	15.8	6.8	324	24.0
Gabon	Nourivit	9.8	5.7	492	4.9
Guinea	Yéolac	14.8	8.1	96	10.8
Niger	Bitamin	15.7	9.4	43	6.6
RD Congo	Cérévap	15.4	6.5	369	7.3
Rwanda	Sosoma	17.8	3.8	500	18.1
Senegal	Ruy Xalel	8.0	5.2	39	5.1
	Provital	9.6	7.4	41	1.9
Togo	Viten 2nd age	15.5	7.6	100	10.9
Minimal recommended value		12.0	8.5	500	16.0

Determination on randomly collected flours in market Source: Trèche *(18)*

The best way to improve hygienic quality seems by popularizing the utilization of the HACCP system even in smaller production units *(16)*.

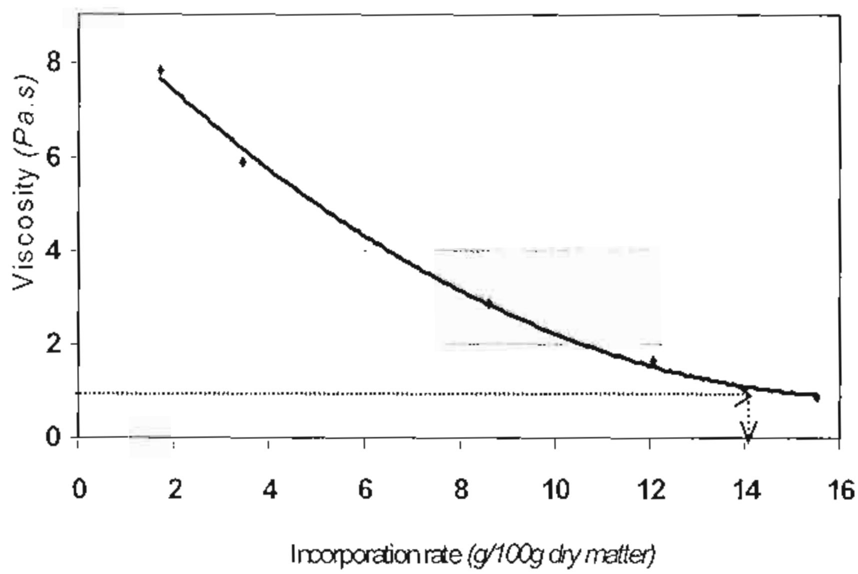
To improve nutrient balance, there is a need to train the heads of production units to choose the adequate sources of protein, lipids, minerals and vitamins and to make an adequate formula.

To improve nutrient bio-availability, heat treatment like roasting and extrusion cooking or biological treatments like fermentation or incorporation of malted flours can be used *(14)*.

To improve energy density of a gruel, it is necessary to induce a partial degradation of starch, which reduces viscosity drastically and allows the preparation of gruels with both higher dry matter content and appropriate consistency. In the contexts of developing countries two ways (i.e., enzymatic or thermo-mechanical hydrolysis) can be proposed to decrease viscosity *(19)*.

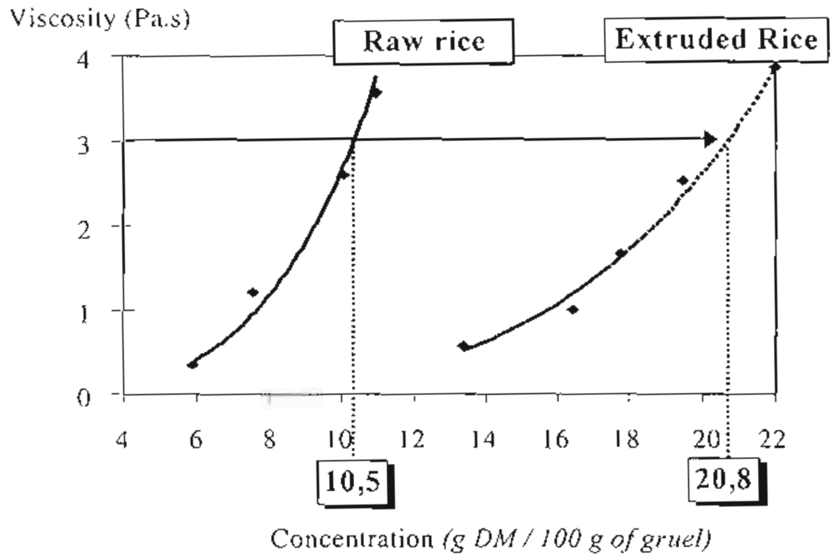
The first way to incorporate malted cereal flours, which can be realized in small-scale production units or at household level. To determine the amount of malted cereal flour needed to prepare a gruel with the appropriate energy density and consistency, all that has to be done is to prepare gruels at required energy density with increasing amounts of malted cereal flour and measure the viscosity of the gruels (Figure 2). Then, on the graph giving the variation of viscosity with amounts of malted cereal flour, it is easy to determine the incorporation rate corresponding to the desired viscosity.

Figure 2: Effect of the incorporation of a malted cereal flour on apparent viscosity (20) of a gruel prepared at an appropriate energy density (120 kcal/100g) from an usual cereal/legume blend.



The second way is by using very low cost extruders of limited capacity, which already exist in some Asian countries. As shown in Figure 3, the maximum acceptable value for viscosity is reached at a concentration of about 10 g of dry matter per 100 g of gruels prepared with raw rice while the concentration corresponding to the same viscosity is almost the double for a gruel prepared from extruded rice.

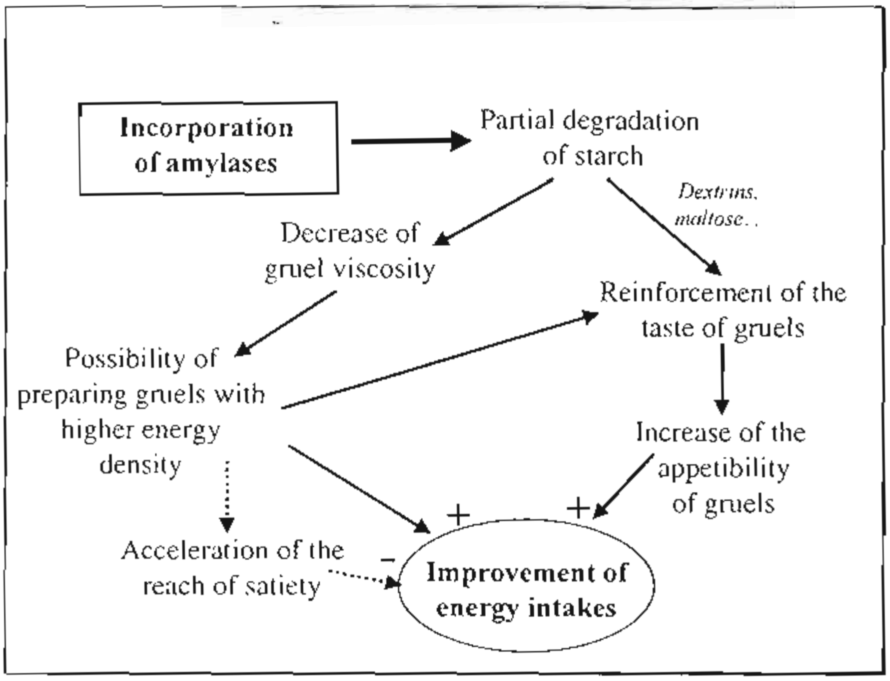
Figure 3: Effect of extrusion cooking on apparent viscosity *(20)* of rice gruels of various concentrations (Mouquet et al, unpublished)



Recent studies have shown that incorporation of a source of amylases into infant flours results in the increase of energy intakes by infants *(21-30)*. Effect of incorporation of amylase can be explained as follows (Figure 4).

Incorporation of amylases results in partial degradation of starch during gruel preparation. This partial degradation into dextrins and maltose probably contributes to increase the sweet taste of the gruel, which improves its appetibility and consequently has a positive effect on food intakes *(7)*. But, above all, partial degradation of starch decreases viscosity, which allows the preparation of a gruel with higher energy density, which strongly influences energy intakes *(6,21-30)*. At the same time the higher energy density may influence the amount consumed by reinforcing the taste of gruels thus increasing its appetibility. However, satiety might be reached sooner, and thus diminishing food intake *(7)*. Finally, the increase of energy intake is the result of the perception by the child of the various modifications induced by the amylase incorporation.

Figure 4: Effect of incorporation of amylases on energy intakes



Potential strategies to improve complementary feeding

To improve complementary feeding in a given context, it is necessary not only to propose practical solutions to make accessible complementary foods with the required characteristics but also to pass on the requisite nutritional knowledge about the best way to use them. Until now, there are two common strategies which include the promotion of complementary foods produced at different levels and the implementation of nutrition education campaigns in order to promote simultaneously adequate feeding practices *(31)*.

The first one consists in the central production and promotion of infant flours at the lowest price. There are numerous examples where large-scale production at national level has failed because of supply or distribution difficulties. Implementation of small production units at local level however seems promising if their heads have sufficient technological and management training. The products which consist in instant flours or flours needing cooking can be sold or distributed within the frame of emergency programmes. Because of the difficulties to establish distribution networks in rural areas, the products are mostly meant for urban families.

The second strategy consists in transfers of technology at household or community level. In order to implement it, mothers need to be trained in the preparation of safe complementary foods with good nutritional value using improved recipes. The targeted infants are mostly those belonging to households with low income living in rural areas.

Alternative strategies can be proposed in some contexts. For contexts where traditional products from small scale production units are frequently used as complementary foods, which is the case for fermented products in various countries, improvement of traditional processes followed by transfer of the improved processes to producers can be an interesting strategy. The number of people to train is considerably lower than in the case of technology transfer at household level. As for the two main strategies presented above, the main difficulty consists in convincing caregivers of the advantages of the improved products.

Another alternative strategy is the central production and promotion of food complements designed for being added to cereal based home made gruels. These food complements have to contain minerals and vitamins, sources of amylases, and eventually sources of protein, lipid and aroma. Their main advantage is that they are considerably cheaper than infant flours and allow the preparation of complementary foods of similar nutritional value and appetibility. Another advantage in rice consuming countries lies in the possibility to add them not only to rice flour but also to traditional preparations obtained by partially crushing rice grains cooked for a long time in an excess of water in order to obtain semi-gruels with acceptable energy density and consistency. These food complements can be sold or distributed in both urban and rural areas.

Conclusion

From this general presentation relative to the importance of complementary foods when promoting growth and development of infants and young children, it would be useful to remember that:

- Access to appropriate complementary foods, in particular at the beginning of the weaning period, is a necessary condition to satisfactory growth and development;
- Complementary foods must have characteristics adapted to the physiological and anatomical constraints of the child and to the socio-economical constraints of developing countries;

- Most of the complementary foods presently used in developing countries are inappropriate;
- There is no universal solution to make appropriate complementary foods accessible to infants and young children: their formulation and manufacturing processes as well as the strategies for promoting their use must be adapted to each context.

Success of strategies depends mainly on the ability of concerned people of different sectors to work together at the conceptual (i.e., between public health scientists and food technologists) and operational levels (i.e., between health services and local complementary food producers).

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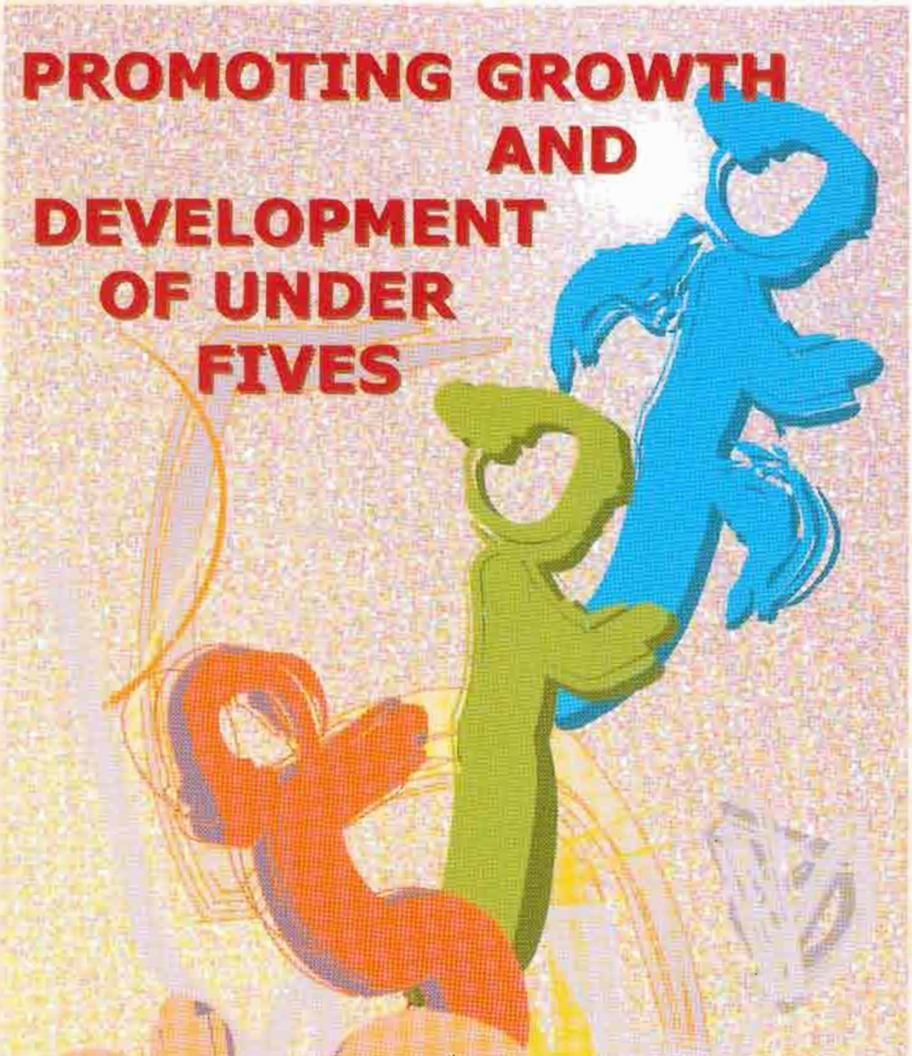
PROMOTING GROWTH AND DEVELOPMENT OF UNDER FIVES



PROCEEDINGS OF THE INTERNATIONAL COLLOQUIUM Antwerp 28-29-30 November, 2001