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Changes in the viscosity and energy density of weaning maize porridge on supplementation with groundnut paste and dairy milk

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Abstract

The effect of replacing 25% of the basic maize flour with groundnut paste (w/w) and/or 10% of the liquid ingredients with fresh dairy milk (v/v) on the viscosity and energy density of weaning maize porridge was investigated in a 2^8 fractional factorial experiment. Other factors investigated included (i) particle size of the flour (ii) concentration of the porridge (iii) cooking time (iv) the temperature of the porridge at the time of viscosity measurement and (v) the shear speed and shear time of the viscometer during viscosity measurements. The viscosity of the porridge was measured using a rotational viscometer while its energy density was determined by calculation from the proximate values of the raw ingredients. The results showed a significant reduction in the viscosity of the maize porridges due to addition of groundnut paste (P<0.001) or fresh dairy milk (P<0.001). Overall, groundnut alone decreased the viscosity of the porridges by 56.1%, milk alone by 26.0% and groundnut plus milk by 64.9%. The influence of the addition of groundnut on the viscosity of the porridges was significantly influenced by concentration of the porridge (P<0.001), shear speed (P<0.01), cooking time (P<0.025) and flour particle size (P<0.05) with groundnut reducing the viscosity more at higher concentrations, lower shear speeds, higher cooking times and with fine particle-sized flour. The influence of addition of dairy milk on the viscosity of the porridges was significantly influenced by concentration (P<0.001) and flour particle size (P<0.05) with milk reducing the viscosity more at higher concentrations and with fine particle-sized flour. The energy density of the porridges was substantially increased by addition of groundnut alone (11.5%), milk alone (25.0%) and groundnut plus milk (36.4%). These results indicate that the viscosity of weaning maize porridges can be reduced and the energy density increased by supplementation with groundnut paste and/or dairy milk. As energy deficit has been found to be the most significant factor in the aetiology of protein-energy malnutrition (PEM), it is therefore recommended that weaning cereal porridges should be supplemented with energy-rich foods.

Key words: Weaning foods, groundnut, milk, maize porridge, viscosity, energy density

Introduction

The low energy density of traditional starch-based weaning foods used in many developing countries, is a major limiting factor in ensuring adequate energy and nutrient intake for infants and young children (FAO/WHO/UNU, 1985). This is particularly serious for cereal porridges (maize, millet and sorghum), the most commonly used traditional weaning foods in many African countries. At the normal drinking consistency (about 7% DM), the porridges have high dietary bulk and very low energy density. As a consequence, large quantities of the porridge would be needed in order to satisfy the child's daily energy and nutrient requirements. However, infants and young children, unlike adults and older children, are unable to consume enough of these porridges because of their small stomach capacity (Cameron and Hofvander, 1983; Lorri and Svanberg, 1993).

Bulky, low energy weaning foods contribute significantly to the aetiology of protein-energy malnutrition (PEM) in developing countries in general (Ljungqvist et al., 1981and Walker, 1990) and in Africa and Uganda in particular (Kakitahi, 1981; Ng'andu and Watts, 1990). The requirement for energy is absolute; i.e. energy must be satisfied before the body can carry out other functions. When the body has a deficient energy intake, it breaks down the protein for energy hence creating a secondary deficiency for protein and paving a way for protein-energy malnutrition (Walker, 1990).

The high viscosity of cereal porridges is a result of the native (unprocessed) starch granules which have a tendency to absorb water and gelatinising during the cooking process (Hellstrom et al., 1981). Various food processing techniques aimed at modifying the native starch and reducing its water absorption capacity have been investigated in order to reduce the viscosity of cereal porridges. These techniques include: extrusion cooking (Jansen and Harper, 1980); germination (Mosha and Svanberg, 1983; Gopaldas et al., 1986 and Svanberg, 1987); fermentation (Tomkins, et al., 1990; Lorri and Svanberg,

1993) and supplementation with energy-rich foods (Marero et al., 1988; Malleshi and Desikacher, 1988). Extrusion cooking reduces the viscosity of the porridges through the action of high temperature and pressure on the starch granules but is too sophisticated and costly to be applicable at village level.

Germination and/or fermentation techniques, commonly used in many African countries, are widely recommended because of their ability to reduce the viscosity of cereal porridges through the action of enzymes (amylases) and acids which break down the starch granules into simple sugars thus reducing their water absorption capacity. However, in many cultures in Uganda, the techniques of germination and/or fermentation are not popularly used in the preparation of weaning foods because they produce flavours which are un-acceptable to the mothers. In a survey carried out in all regions of Uganda, Sserunjogi and Tomkins (1990) and in the Central region, Kakuramatsi-Kikafunda (1996) found that use of germinated/fermented weaning foods was not a widely accepted weaning practice.

In areas where germination and/or fermentation techniques are not popular, supplementation of the basic cereal flour with energy- and nutrient-rich foods has been recommended as the most practical and cheapest method of producing a weaning food of high nutritional status (Moussa et al., 1992). However, previous studies on supplementation have concentrated on single nutrient foods such as oil and/or sugar (Srikantia, 1979 and Dearden et al., 1980) which, in addition to being too expensive for most rural families, may jeopardise intake of other nutrients, particularly proteins. A few cereal/legume combinations have been investigated by various researchers but almost all these involved the germination and/or fermentation techniques (Marero et al., 1988; Malleshi and Desikacher, 1988). Not much work was found in the literature concerning un-germinated/un-fermented cereal/legume blends. It is known that the particle size of the flour, concentration of the porridge, length and temperature of cooking, temperature at time of consumption and the time and speed the food is chewed in the mouth have an effect on the viscosity of cereal porridges (Walker and pavitt, 1989; Lorri and Svanberg, 1993). However, the extent to which these variables affect the viscosity and their interactions with supplemented ingredients has not been fully examined.

The purpose of this study was therefore, to investigate the effect of adding easily accessible energy- and nutrient-rich foods (groundnut and milk) on the viscosity and energy density of un-germinated/un-fermented weaning maize porridges, under different influencing factors.

Materials and methods

Materials

Maize grains (*Zea mays*, var. Kawanda Composite) were obtained from Namulonge Research Station (Uganda) by air freight to The University of Reading, UK, where the study was conducted. On arrival, the maize was stored for one week at -18 °C to destroy any insect pests after which it was stored at 10 °C until use. Dry groundnut (*Arachis hypogaea*) grains were purchased from Reading University Food Stores and kept in tightly closed food jars. The milk was fresh pasteurised whole dairy milk purchased from the University of Reading Cold Food Stores.

Methods

Chemical methods. The chemical composition (proximate analysis) of the main ingredients (maize and groundnut) was determined using mostly the Association of Official Analytical Chemists (AOAC, 1980) methods. To prepare the samples for chemical analysis, the maize grains were ground into a powder using a cyclone sample mill (Tecator Cyclon 1092, Tecator Co. USA). The groundnut grains were ground into a paste using a 60 g capacity Moulinex coffee grinder (Moulinex Super Junior "S", 31 Route d'Ancinnes, BP 185, 61002 Alencon Cedex, France) each small batch of 50 g being ground at maximum speed for 60 seconds. As the high fat of the groundnut paste would interfere with the analysis of other nutrients, the paste was defatted using the method of Egan et al. (1981). The resulting meal was dried at (100 $\pm$ 1 °C) until constant weight and re-ground into a powder using the Moulinex coffee grinder.

The moisture content of the raw materials (maize powder) was determined using the AOAC (1980) air oven method No. 14.003. The total protein content of both the maize and groundnut materials was determined using the Organic Nitrogen-Protein Analyser (Leco FP228, Leco Instruments (UK) Ltd., Newby Road, Hazel Grove, Stockport, SK7 5AD, Cheshire) following the manufacturer's instructions. The conversion factor of N x 6.25 was used for maize and N x 5.41 for groundnut as recommended by AOAC (1984). Utilisable carbohydrates (water soluble carbohydrates and starch) was analysed using a combination of methods based on cold water extraction, acid hydrolysis and automated colorimetric assay as described by Fuller (1968) and Southgate (1991). Fat in samples was determined following the method described by Egan et al. (1981) using a Tecator Soxtec System (HT 1043 Extraction Unit, Tecator Co. USA). The chemical composition of maize and groundnut is presented in Table 1.

Preparation of maize porridge. The maize flour for preparation of the porridges was made by grinding the maize grains with a Christy and Norris laboratory hammer mill (No. 8) (Christy and Norris Ltd., Broomfield Road, Chelmford CM1 1SA, England) with a 1.6 mm mesh screen for the flour designated as "coarse" and a 0.8 mm mesh screen for the flour designated as "fine". Particle size distribution of the maize flours was determined using a Silent Sieve Shaker (Fritsch Spartan Analysatte 3 E, Christson Scientific Equipment, Ltd., UK). The oscillation amplitude was set at 3 (range of 1-10) and the time of sieving at 10 minutes. The resulting particle size distribution for the coarse and fine flours is presented in Table 2. The actual flour used for the preparation of the porridges, however, was not sieved. The groundnut grains were ground into a smooth paste using a Moulinex coffee grinder (Super Junior "S") at maximum speed, each small batch of 50g ground for 60 seconds.

The method of porridge preparation was based on the traditional method of porridge preparation used in Uganda, which basically involves mixing the flour with water to form a slurry which is then heated while stirring. The method was adapted to laboratory conditions using the methods of Mosha and Svanberg (1983) and Pavitt (1987) with some modifications. The required ingredients were calculated and carefully weighed. Maize flour of two particle sizes (coarse and fine) at two concentrations (6% and 8%) were used. To prepare a 200 ml, 8% maize porridge (with no groundnut or milk added), 16 g of maize flour were weighed into a weighed 250 ml Pyrex beaker and 20 ml of cold distilled water added to make a smooth slurry. One hundred and sixty four millilitres (164 ml) of boiling water was added to the slurry with constant stirring using a metal spatula and the mixture heated on a full Bunsen flame until the temperature reached 100 $\pm$ 1 °C. The heat was then reduced to a quarter Bunsen flame and the mixture simmered at this temperature, with gentle but constant stirring, until the required time of cooking (5 or 10 min), as dictated by the experimental design, was reached. Where groundnut paste and/or fresh dairy milk were to be added, these were calculated to replace 25% (w/w) of the basic maize flour and 10% (v/v) of the water, respectively.

Viscosity determination. Viscosity of the porridges was measured in milli Pascal seconds (mPa.s) using a rotational viscometer, a Haake Rotovisco RV3 (Haake Mess-Technik GmbHu Co. Dieselstraße 6 D-7500 Karlsruhe 41, Germany) following the manufacturer's instructions. Rotational viscometers are recommended for viscosity measurements of thixotropic materials (Dinsdale and Moore, 1962). The temperature in the viscometer was controlled by a temperature control vessel connected to a temperature controlled water bath that kept the water at the required temperature (30 °C or 40 °C) as dictated by the experimental design. The beakers containing the cooked porridges were cooled in this water bath for 90 minutes after which the test material was carefully transferred to the viscometer sample cup and left for 5 minutes for equilibration before measurements were taken. The shear speed (256 or 512 rpm) and shear time (20 or 60 seconds) of the viscometer were set as dictated by the experimental design.

Energy density determination. The energy density of the porridges was determined by calculation using the proximate analysis values of the raw materials presented in Table 1.

Experimental design. Two levels each of groundnut (0 or 25% replacing the maize flour, w/w) and dairy milk (0 or 10% replacing the water, v/v) and other factors that can influence the effect of these supplements were tested in 2^8 fractional factorial experiment. The other factors investigated were: particle size of the flour (Table 2), concentration (6 or 8%), cooking time (5 or 10 min), temperature of the porridges at time of measuring (30 or 40 °C), shear speed (256 or 512 rpm) and shear time (20 or 60 sec.). The ranges set for these variables were the practical ranges; for example normal eating temperatures of 30 - 40 °C. The ¼ replicate method of Cochran and Cox (1957) was employed which reduced the treatment combinations from 256 to 64. Treatments were randomised and divided into 4 blocks of 16 treatments, each block representing a different day in order to check day-to-day variations, thus checking the reproducibility of the methods. The treatments and their levels are shown in Table 3. Analysis of variance (ANOVA) was carried out using the General Linear Model of SAS (Statistical Analysis System, SAS Institute, Inc., Cary, USA).

Table 2. Particle size distribution of the coarse and fine maize flour

Sieve size (µm)	Coarse flour (1.6 mm mesh screen)		Fine flour (0.8 mm mesh screen)	
	Wt. of flour (g)[1]	% flour[2]	Wt. of flour (g)[1]	% flour[2]
850	3.03	96.97	1.10	98.90
710	9.10	87.87	0.43	98.47
600	62.38	25.49	1.86	96.61
425	12.44	13.05	52.57	44.04
300	11.15	1.99	38.17	5.87
250	0.76	1.14	2.65	3.22
150	0.42	0.72	2.50	0.72
75	0.30	0.42	0.40	0.32

[1] Weight (g) of flour remaining on the sieve
[2] Percent (%) flour passing through the sieve

Table 1. Proximate composition of the raw materials used in preparation of the porridges [values[1] are expressed as per 100 g edible portion]

Material	Moisture (%)	Total protein[2] (%)	Total fat (%)	Utilisable carbohydrate (%)	Energy kJ/100 g
Maize	10.00	9.72	4.30	72.61	1538.32
G. nut	9.53	26.41	42.62	11.32	2233.88
Milk[3]	87.00	3.20	4.00	4.70	282.57

[1] Values are means of duplicate samples
[2] The conversion factor of N x 6.25 was used for maize and N x 5.41 for groundnut
[3] The values for dairy milk were those on the label of the milk package

Results

Viscosity

Overall, the main treatment variables were significant in influencing the viscosity of the maize porridges. The least square means (LSM) of the viscosity of the eight treatment factors and their levels of significance is presented in Table 4. Changes in concentration and addition of the supplements had the greatest effect on the viscosity of the porridges.

Table 3. Main treatment factors and their levels

Factor	Level	Values
Groundnut	0%	25%[1]
Cow's milk	0%	10%[2]
Particle size	Coarse	Fine
Concentration	6%	8%
Cooking time	5 min.	10 min.
Temperature	30 °C	40 °C
Shear speed	256 rpm	512 rpm
Shear time	20 sec.	60 sec.

[1] Groundnut replacing 25% of the maize flour (w/w) equivalent to 3.0 g and 4.0 g of groundnut at 6% and 8% concentration, respectively.
[2] Cow's milk replacing 10% of the water (v/v) equivalent to 18.4 ml and 18.8 ml of milk at 6% and 8% concentration, respectively.

Table 4. Least square means (LSM)[1] for main treatment factors

Variable	Levels	Mean viscosity (mPa.s)	P value
Groundnut	0%	214.51	P<0.001
	25%	87.50	
Milk	0%	176.13	P<0.001
	10%	125.82	
Particle size	Coarse	136.44	P<0.01
	Fine	165.51	
Concentration	6%	68.13	P<0.001
	8%	233.80	
Cooking time	5 min.	128.12	P<0.001
	10 min.	173.83	
Measurement	30 °C	161.20	P<0.025
Temperature	40 °C	140.73	
Shear speed	256 rpm	180.14	P<0.001
	512 rpm	121.89	
Shear time	20 sec.	156.90	(NS)
	60 sec.	145.02	

[1] Least Square Means refer to the means that have been adjusted to take account of the incomplete nature of the experimental design

Effect of supplementation with groundnut and/or milk on the viscosity of the porridges

The viscosity of the maize porridges was significantly ($P<0.001$) reduced by replacing 25% of the maize flour with groundnut paste (w/w) or replacing 10% of the water with fresh dairy milk (v/v). The viscosity of the porridges was also significantly decreased by increasing shear speed ($P<0.001$). On the other hand, the viscosity of the porridges was significantly increased by use of flour of a fine particle size ($P<0.01$), increasing concentration ($P<0.001$) and increasing cooking time ($P<0.001$). Increasing temperature mildly ($P<0.025$) reduced the viscosity of the porridges. Shearing time had no significant effect on porridge viscosity.

There were a number of significant interactions between the supplements and other treatment variables. The effect of adding groundnut on the viscosity of the porridges as influenced by the other treatment variables is shown in (Fig. 1a) and (Fig. 1b) for coarse and fine textured flours, respectively. The reducing effect of groundnut on the viscosity of the porridges was significantly ($P<0.05$) influenced by flour particle size. Groundnut decreased the viscosity of both the coarse and fine particle flour porridges but the reduction was more with the fine particle flour (Fig. 1a and 1b). Averaging the rest of the treatment combinations, the addition of groundnut reduced the viscosity of the porridges by 57.4% for coarse textured flour compared to 60.7% for fine textured flour. The reducing effect of groundnut significantly ($P<0.001$) interacted with concentration with groundnut reducing the viscosity more at higher concentrations for the fine particle flour porridges. Averaging all the treatment combinations for the fine particle flour, the addition of groundnut reduced

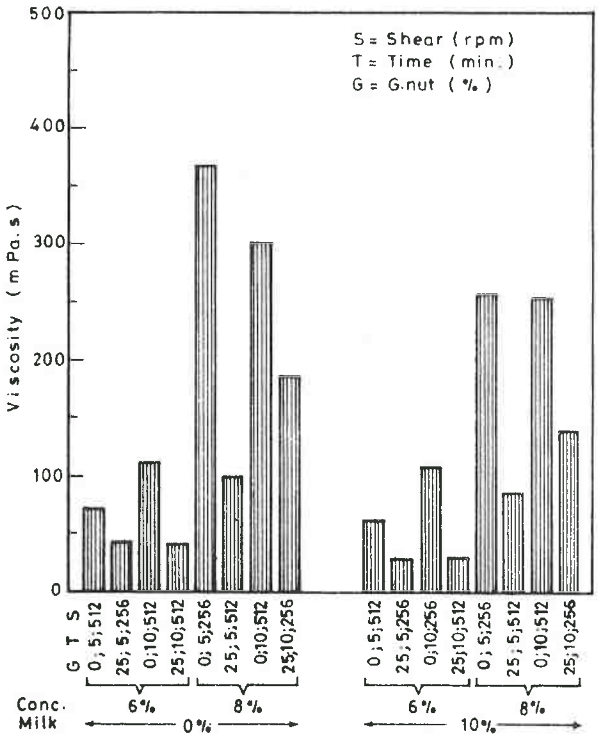

Fig. 1a. Effect of adding groundnut on the viscosity of the porridges as influenced by coarse textured flours

the viscosity of the porridges by 36.3% at 6% concentration compared to 66.5% at 8% concentration, almost two-fold (Fig. 1b). For the coarse textured flour, the reducing effect of groundnut was almost similar at both concentrations as the supplement reduced the viscosity by 59.2% and 56.8% at the 6% and 8% concentration, respectively (Fig. 1a). Groundnut interacted significantly ($P<0.01$) with shear speed, with addition of groundnut reducing the viscosity of the porridges more at higher shear speeds. Groundnut also mildly interacted with cooking time ($P<0.025$), with groundnut being more effective at higher cooking times.

The reducing effect of milk on the viscosity of the porridges as influenced by other variables is shown in (Fig. 2a) and (Fig. 2b) for the coarse and fine textured flour, respectively. Milk significantly ($P<0.05$) interacted with particle size of the flour with milk being more effective in reducing the viscosity of the fine particle sized flour. Averaging the rest of the treatments, milk reduced the viscosity of the porridges by 21.0% for the coarse textured flour compared to 34.4% for the fine textured flour. The interaction between concentration and milk was highly significant ($P<0.001$) with addition of milk reducing the viscosity of the porridges more at the higher concentration especially for the fine particle flour. At 8% concentration, there was a 22.7% reduction in the viscosity due to addition of milk compared to 14.7% at 6% concentration for the coarse textured flour. With fine textured flour, however, the reduction in viscosity was double at the higher concentration; 38.3% at 8% concentration compared to 19.5% at 6% concentration (Fig. 2b).

The combined effect of supplementing the porridges with groundnut and milk on reducing the viscosity of the

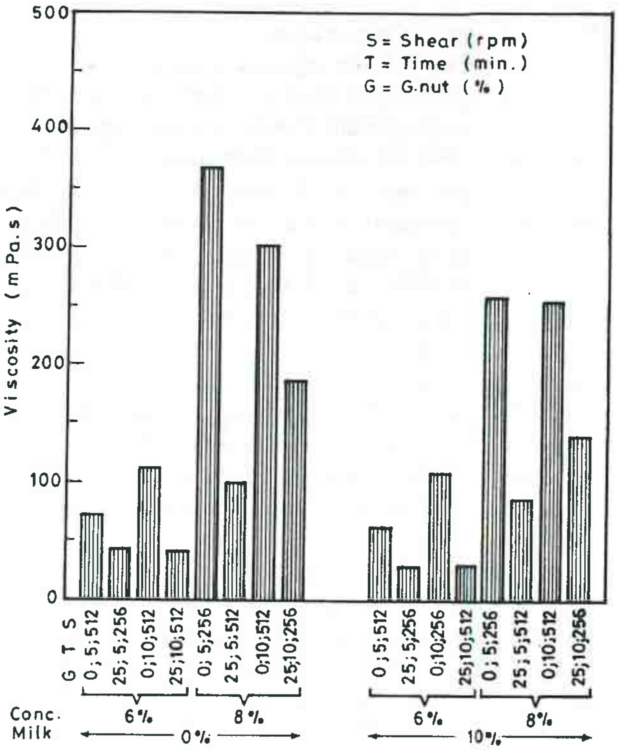

Figure 2a. Reducing effect of milk on the viscosity of the porridges as influenced by course textured flours

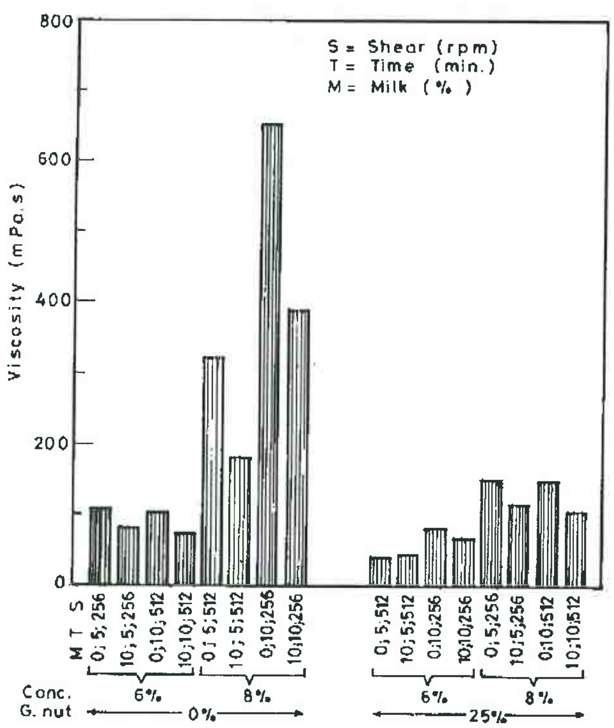

Fig. 1b. Effect of adding groundnut on the viscosity of the porridges as influenced by fine textured flours

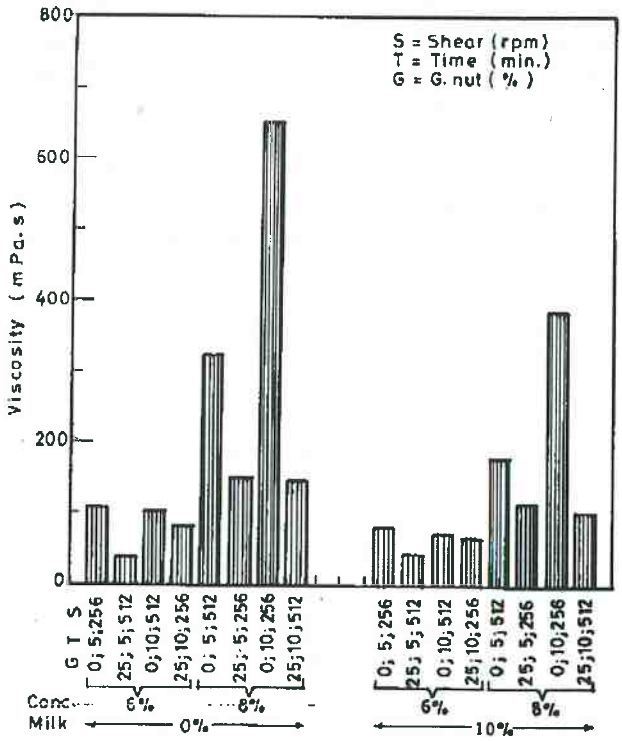

Figure 2b. Reducing effect of milk on the viscosity of the porridges as influenced by fine textured flours

maize porridges was significant ($P<0.01$) but not additive. Groundnut alone reduced the viscosity of the porridges by 56.1%, milk alone by 26.0% and groundnut plus milk by 64.8%.

Energy density of the porridges

The influence of addition of groundnut and/or dairy milk on the energy density of the maize porridges is presented in Table 5. Supplementation with groundnut and/or milk significantly ($P<0.001$) increased the energy density of the porridges. Replacing 25% of the maize flour with groundnut increased the energy density of the 6% and 8% porridges by almost an equal degree of 11.4% and 11.6%, respectively. Replacing 10% of the water with milk increased the energy density of the 6% and 8% porridge by 28.2% and 21.7%, respectively. Adding both groundnut and milk increased the energy density of the 6% and an 8% porridge by 39.5% and 33.2%, respectively. Averaging the two concentrations (6% and 8%), the energy density of the porridges was increased by 11.5, 24.9% and 36.4% by the addition of groundnut alone, milk alone and groundnut plus milk, respectively.

The energy density of the porridges was also significantly ($P<0.001$) increased by increase in concentration. For example, a 6% porridge (with no supplements) had an energy density of 22.1 kcal (92.4 kJ) per 100 g compared to 29.4 kcal (122.9 kJ) for the 8% porridge; a 33.0% increase in energy density.

Discussion

Viscosity

Viscosity by definition is resistance to flow. Any substance that interferes with a material's ability to flow will increase its viscosity and that which assists a material to flow will decrease its viscosity. The results of the above experiment show that the viscosity of the porridges were significantly reduced by addition of a small amount of groundnut paste. The mechanism by which groundnut and milk reduce the viscosity of the porridges is through their high fat content. Fat reduces viscosity in two ways; through formation of insoluble complexes with the polysaccharide chains and/or formation of a fatty layer around the starch granules (Collison, 1968). Both methods reduce the water absorption capacity of the starch granules during the cooking process thus reducing viscosity. Groundnut was more effective in reducing the viscosity of the porridges than dairy milk because of the former's higher fat content.

Fine particle-sized flours, high concentrations and prolonged cooking times have been shown, in this experiment, to significantly increase the viscosity of the porridges. With a more fine particle sized flour, more starch granules and a larger surface area per granule are exposed to take part in the gelatinisation process and hence increase viscosity. At higher concentrations, there are more starch granules to interfere with the flow properties of the porridge. With prolonged cooking times, most of the water evaporates leaving a more viscous porridge. This is unavoidable as maize starch is quite resistant to heat and needs to be well cooked to avoid indigestion and diarrhoea. Viscosity has an inverse relationship with temperatures; as temperatures decreases, viscosity increases (Bourne, 1982). This is because, on cooling, the molecules re-structure themselves into a tight network. The viscosity of the porridges decreased with increasing shear speed and shear time. This is a characteristic of non-Newtonian, thixotropic materials (materials which thin on shear), such as cereal porridges, due to the dis—entangling of the polysaccharide chain. These two variables simulate what goes on in the mouth.

Energy density

Energy density of a food is the energy content per 100 g of food (FAO/WHO/UNU, 1985). The addition of small amounts of groundnut and/or milk significantly ($P<0.001$) increased the energy density of the maize porridges. The overall high nutrient density of groundnut (high protein and high fat; Table 1) is responsible for the increased energy content of the porridges. Afolabi et al. (1988) investigating the nutritional status of 3:1 maize:groundnut blends found that the blends had higher energy, protein and fat contents than un-supplemented blends. The supplemented blends were also quite acceptable by both mothers and children.

In Uganda and in other African countries, maize-soybean weaning mixtures are more common than maize-groundnut blends. In a comparative study of the two legumes as cereal supplements, Fashakin and Ogunsola (1982) compared 3:1 blends of maize:soya bean and maize:groundnut and concluded that the maize:soya bean blend had superior quality protein than the maize:groundnut blend. However, in view of the fact that soya bean requires sophisticated processing of high temperature/high pressure to inactivate the anti-trypsin factors, processes not easily available at village level, use of groundnut could continue to be promoted as a practical solution to the dietary bulk and energy density problems of infants' and young children's foods in developing countries. In recommending use of groundnut in child feeding, the mothers need to be educated on proper drying and storage of the nuts to avoid contamination by the mould *Aspergillus flavus* that produces the carcinogenic

Table 5. Effect of addition of groundnut and/or dairy milk on the energy density (kJ/100 g) of maize porridges (energy density was calculated from the proximate values in Table 1)

Solids (%)	Maize alone	Maize+ Groundnut	Maize+ Milk	Maize+Groundnut +Milk
6	92.42	102.95	118.46	128.91
v	122.98	137.19	149.64	163.86

poison, *Aflatoxin,* which has been implicated in the pathogenesis of PEM (Hendrickse, 1988). Unexpectedly, addition of milk had more effect on the energy density of the porridges than addition of groundnut even when the latter has a higher energy density per 100 gram. This was because only a small amount of groundnut was used (3 and 4 g for the 6% and 8%, respectively) and this replaced some of the maize flour while milk replaced only water.

Dietary bulk

Dietary bulk refers to the volume and consistency (viscosity) characteristics of a diet. High volume/high viscosity and low energy density of a food make it difficult for an individual to consume enough of that food to meet nutritional requirements (Ljungqvist et al., 1981; Svanberg, 1987). Physiological factors related to dietary bulk, which are important in child feeding include chewing, swallowing, digestion, absorption and gastric emptying (Svanberg, 1987). The phenomena of viscosity and energy density are interrelated and are important in infant foods and feeding because the child is learning new eating skills; changing from a predominantly liquid diet to a predominantly mashy/ solid diet (Walker and Pavitt, 1989). A concentrated porridge is more energy dense than a dilute one but it is highly viscous and young children have difficulties in consuming food of high viscosity (Mosha and Svanberg, 1983). Traditional cereal weaning porridges exhibit both pseudoplastic and thixotropic characteristics (Walker and Pavitt, 1989). Their viscosity decreases with increasing shear speed but on standing and cooling, the molecules re-group themselves and viscosity increases again. These physico-chemical characteristics present practical problems to the mother on how to best feed the porridge to the infant.

The energy density of weaning foods in developing countries is usually low and may be only a third of the energy density of weaning foods in developed countries (Walker, 1990). A typical weaning maize porridge of drinking consistency has about 7-8% solids and would provide a child of 12 months of age with only half the calories he/she needs for growth (Kakuramatsi-Kikafunda, 1996). This is a problem not only the child who has been removed from the breast but also for the child who is still breast feeding because these highly bulky porridges fill the child's stomach and reduce his/her suckling ability. Unlike adults and older children, the stomach of a young child has a small capacity and can only take in about 200-300g at one sitting (Cameroon and Hofvander, 1983). This makes it practically impossible for young children to meet their energy and nutrient needs on these low energy foods alone. However, from the results of the present study, it has been shown that supplementation of cereal porridges with energy-rich foods such as groundnut paste and/or dairy milk can reduce their viscosity while increasing their energy of the porridges thus making them appropriate foods for child weaning.

Conclusion

It has been established from this study that replacing 25% of the flour with groundnut paste (w/w) and 10% of the water with milk (v/v) can result in a significant reduction in the viscosity and a substantial increase in the energy density of weaning maize porridges. It was further established that the added supplements can significantly interact with other porridge parameters such as flour particle size, porridge concentration, cooking time etc. Further research is needed to establish the acceptability of the supplemented porridges by both mothers and children.

In conclusion, low cost technology methods that reduce the viscosity while increasing the energy density of weaning cereal porridges, particularly supplementation with high energy foods, are very beneficial and are recommended in the production and preparation of weaning foods, especially in developing countries.

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