EFFECT OF ADDITION OF MALTED AND FERMENTED SORGHUM FLOURS ON PROXIMATE COMPOSITION, VISCOSITY, pH AND CONSUMER ACCEPTABILITY OF EXTRUDED SORGHUM WEANING PORRIDGES

S M Wambugu[1], J R N Taylor[2] and J Dewar[3]

[1]Kenya Industrial Research & Development Institute, (KIRDI) P O Box 30650, Nairobi-Kenya,
E-mail: wambugu@kenyaweb.com

[2]Department of Food Science, University of Pretoria 0002, Pretoria, South Africa,
E-mail: jtaylor@postino.up.ac.za

[3]CSIR, P O Box 395, Pretoria 0001, South Africa,
E-mail: jdewar@csir.co.za

The effects of addition of different proportions of fermented and malted sorghum flours on the proximate composition, viscosity, pH and consumer acceptability of extruded instantised sorghum weaning foods were evaluated. The main objective was to increase the nutrient density of the weaning porridges through viscosity reduction, since low nutrient density has been identified as major obstacle in young child feeding.

The extrudates did not differ greatly in their proximate composition. Addition of malted sorghum flour resulted in porridges with greatly reduced viscosities (1000-3000 cP). However, its addition caused an overall reduction in consumer acceptance. Addition of fermented sorghum flour resulted in some viscosity reduction, although not to the same extent achieved by malt addition. Samples made from plain and plain/fermented materials seemed to appeal to a number of consumers.

It is concluded that porridges made from composites of extruded plain/malted/fermented sorghum flours seem to offer the best route to address the identified problem of child nutrition. To improve product consumer acceptability, it is recommended that approved food colours and flavours be incorporated in the extruded sorghum weaning foods.

INTRODUCTION

One of the major nutritional problems faced by young children in the eastern and southern African region during the weaning period is that weaning foods (which are commonly prepared in the form of porridges) made from the major staple foods (mainly cereals and roots and tubers) found in the region have a low nutrient density, mainly because they are high in unmodified starch and low in fat. Such porridges usually contain around 5-10% dry matter, which would give 84–168 kJ 100 g of prepared food[1]. A young child must consume a large volume of this porridge if its energy and other nutrient requirements are to be met during the period when breast milk alone is insufficient. Many children are unable to eat such quantities mainly by virtue of their small stomachs, resulting in insufficient intakes of energy, protein, and other nutrients. The problem is compounded if children are fed infrequently (because of other demands on the mother's time) or if appetite is reduced because of illness[2].

To improve the nutrient intake of weaning-age children, several food preparation technologies have been advocated that effectively increase the nutrient density of weaning porridges and reduce the risk of infection from them. The addition of a small quantity of germinated sorghum flour, rich in the enzyme, alpha-amylase, to thick cereal porridges is known to improve the digestibilities of storage proteins and starch, and to dramatically reduce the viscosity of such porridges, thus allowing for the preparation of a more nutrient-dense food that is sufficiently liquid for a young child to consume[3].

Non-alcoholic fermentation of cereals for a limited period of time has been found to improve the amino acid composition and vitamin content, increase protein and starch digestibilities, increase the bioavailability of minerals, and to lower the levels of antinutrients[4]. However, despite many allusions in the literature as to the viscosity-reducing effect of fermentation[5,6], this is rarely substantiated and there has been little work specifically addressing the effect of fermentation on viscosity and energy density[7]. The findings are highly contradictory, and appear to vary according to the method of fermentation and particularly the microorganism responsible[7].

Extrusion has also been found to cause substantial reduction in the viscosity of cereal gruels[8-10] thereby enhancing their nutrient densities. High temperature short time (HTST) extrusion cooking also causes an increase in the microbiological safety and shelf-life of the food through destruction of pathogenic and spoilage microorganisms[11].

The objective of this study was to increase the nutrient density of the sorghum weaning porridges through viscosity reduction, since low nutrient density has been identified as major obstacle in young child feeding.

EXPERIMENTAL

Condensed tannin-free sorghum (*Sorghum bicolor* (L.) Moench) variety Local White was obtained from Kenya Industrial Research and Development Institute (KIRDI) in Kenya and airfreighted to the Division of Food Science and Technology of the Council for Scientific and Industrial Research (CSIR), South Africa. On arrival, the sorghum was stored at 10°C until use. The grain was cleaned to remove stones, dust and light materials, glumes, stalks, broken, undersized and immature grain. This was done using an Emceka machine (Augsburg, Germany) fitted with 1.4 mm aperture-size screen. Part of the grain was set aside for malting while the rest was decorticated using Miag Braunschweig pearling cone dehuller (Augsburg, Germany). A yield of 76% was achieved after passing the sorghum twice through the dehuller. The dehulled grain was then milled using an Alpine Augsburg universal hammer mill type 25A (Augsburg, Germany) fitted with a 1.4 mm screen. The milled samples were then packed in airtight black plastic bags and stored at 10°C. Part of the flour was milled though a 0.8 mm screen and set aside for fermentation. Fermented and malted sorghum flours were prepared according to standardized procedures[12]. Ten formulations (Table I) were prepared in duplicate from the above ingredients, their moisture contents adjusted to 18% by the addition of the requisite amount tap water containing calcium chloride such that a 200 ppm calcium chloride concentration (expressed as Ca^{2+}) was achieved in each of the final products. After blending in a helical mixer each sample was extruded using a Werner & Fleiderer type: Continua 37/22D twin-screw extruder (Stuttgart, Germany) under the following conditions: extrusion temperature (at the die) – 173°C; die size – 3 mm; product feed rate – 250 g/min; screw speed - 200 rpm; palletising/cutter speed - 30 rpm; L: D ratio –12; screw diameter – 37 mm. The extruder screw-configuration is shown in Table II. The extruded samples were allowed to cool for about 2 h and then hygienically stored in woven polythene bags at room temperature for about 16 h (to allow drying and moisture equilibration). The dry extrudates were roller-milled using a pilot-scale Castrol Alpha roller mill model SP 150 (Augsburg, Germany). The gap between the fast roller (set at 236 rpm) and the slow roller (set at 200 rpm) was 4 mm during the first pass and 0.1 mm during the second and third passes. Each of the rollers had 7 flutes per cm on its surface. The milled samples were then stored in polythene bags at 10°C. The viscosity of each of the samples was finally measured at 20% (w/w) using a Rapid Visco Analyser model RVA 3D+ (Newport Scientific, Warriewood, Australia) at 40°C. Each RVA canister was loaded with 28 g of 20% (dry weight basis) extrudate in distilled water (at 92°C). Viscosity determinations were done in triplicate. The RVA profile was used is shown in Table III.

RESULTS

Table IV shows that there was a significant difference between the viscosities of the sorghum weaning porridges. Addition of malted and fermented sorghum flours, either individually or in combination, resulted in porridges having lower viscosities than the control sample. However, addition of malt flour caused a greater viscosity reduction than

Sample	Sample composition
Sample P (100)	Plain dehulled sorghum flour (control sample)
Sample PM (25:75)	Plain dehulled sorghum flour: malted sorghum flour
Sample PM (50:50)	Plain dehulled sorghum flour: malted sorghum flour
Sample PM (75:25)	Plain dehulled sorghum flour: malted sorghum flour
Sample PF (25:75)	Plain dehulled sorghum flour: fermented sorghum flo
Sample PF (50:50)	Plain dehulled sorghum flour: fermented sorghum flo
Sample PF (75:25)	Plain dehulled sorghum flour: fermented sorghum flo
Sample PMF (50:25:25)	Plain dehulled sorghum flour: malted sorghum flour: (50%: 25%: 25%).
Sample PMF (25:50:25)	Plain dehulled sorghum flour: malted sorghum flour: (25%: 50%: 25%).
Sample PMF (25:25:50)	Plain dehulled sorghum flour: malted sorghum flour: (25%: 25%: 50%).

Table I Composition of sorghum weaning food formulations used in the study

No. of screw units	Length of individual units (mm)	Pitch (mm)
9	50	40
5	30	40
1	50	40
2	20	26
1	10	40
1	30	40
2	10	40
1	30	40
2	10	40
1	30	40

* The total effective screw-length was 830 mm.

Table II The extruder screw-configuration used to extrude sorghum weaning food formulations*

Time	Type	Value
00:00:00	**Temp.**	**92°C**
00:00:00	**Speed**	**960 rpm**
00:00:10	**Speed**	**160 rpm**
00:02:00	**Temp.**	**92°C**
00:07:00	**Temp.**	**40°C**
00:36:00	**Temp.**	**40°C**

*NB: Idle temperature: 92 ± 1°C; End of test: 36.5 min; Time between readings: 4 sec.

Table III RVA profile that was used in the determination of the viscosities of the sorghum weaning porridges

did the addition of fermented sorghum flour. Samples containing a combination of plain (P), malted (M) and (F) fermented sorghum flours had lower viscosities than those containing P or F flours. The sample containing P sorghum flour had the highest final viscosity (3584 cP) while sample PMF (25:25:50:) had the lowest final viscosity (2364 cP).

Component	**P (100)** [x]	**PM (75:25)**	**PM (50:50)**	**PM (25:75)**	**PF (75:25)**	**PF (50:50)**	**PF (25:75)**	**PMF (50:25:25)**	**PMF (25:50:25)**	**PMF (25:25:50)**
Mean viscosity (cP)	3584[i]*	2590[d]	2498[b]	2527[c]	3441[h]	3264[g]	2944[f]	2827[e]	2567[d]	2364[a]

* Values having different characters differ significantly from each other ($p < 0.05$).
**Viscosity measured at 20% (w/w) using a Rapid Visco Analyser (90059. RVA 3D+) at 40°C. Mean values of three replicates are reported.
x Ratios in brackets represent the mixing/blending ratios of the various weaning food ingredients.
P = Plain sorghum flour obtained by dehulling and milling of Kenyan Local White sorghum grain.
M = Malted sorghum flour obtained by dehulling and milling of malted Kenyan Local White sorghum grain.
F = Fermented sorghum flour obtained by fermenting and milling of Kenyan Local White sorghum grain flour (P).

Table IV Viscosity **(cP) of roller-milled extruded sorghum weaning porridges**

As shown in Figures 1 to 10, a slight initial increase in viscosity occurred in all the samples during the heating phase of the pasting curve. During holding at 92°C for 2 min, the viscosities of samples P (100) (Fig. 1), PM (75:25) (Fig. 4) and PMF (25:25:50) (Fig. 10) temporarily reached a plateau while the viscosities of samples PM (25:75) (Fig. 2), PM (50:50) (Fig.3) and PMF (25:50:25) (Fig. 9) decreased sharply. The rates of rise in the viscosities of samples PM (50:50) (Fig. 3), PF (25:75) (Fig. 5), PF (75:25) (Fig. 7), and PMF (50:25:25) (Fig. 8) decreased slightly as indicated by the small shoulders on each of the graphs. When the cooling phase was started (cooling from 92°C to 40°C), the viscosities of all the samples increased rapidly.

A very interesting observation was the appreciable decline in viscosities of samples PM (25:75) (Fig. 2), PM (50:50) (Fig. 3) and PMF (25:50:25) (Fig. 9), slight decreases in samples PMF (50:25:25) (Fig. 8) and PMF (25:25:50) (Fig. 10) and no increase or decrease in the viscosity of sample PM (75:25) (Fig.4) on maintaining the temperature at 40°C for 30 minutes with continuous stirring at 160 rpm. All these samples contained malted sorghum flour as an ingredient. In contrast, the plain sorghum sample (P (100) (Fig. 1)) and the samples containing fermented sorghum flour but no malt flour (Figs. 5, 6 and 7) had their viscosities increasing continuously during the period that the temperature was maintained at 40°C

According to one researcher[13], in gruels based on cereals, the viscosity resulting from starch gelatinisation is the most important determinant of energy density. The viscosity of these gruels in turn depends in large part on the degree of gelatinisation. Other researchers[14,15] found that extrusion cooking produces a virtually complete starch gelatinisation at low moisture content when the temperature exceeds 110-135°C. This is as a result of the combination of heat treatment and mechanical shear, which causes the disappearance of starch granular structure and starch crystallinity in the extruded materials. The findings of this study strongly suggest that the extrusion conditions employed resulted in adequately cooked products that required only reconstitution with freshly boiled water before feeding the child. Indeed, actual tasting of the extrudates indicated that they were well cooked, since no raw starch taste was discernible.

All the weaning food porridges (20% solids) containing malted sorghum flour as an ingredient had a semi-liquid consistency (1000-3000 cP) which has been proposed as being suitable for cereal-based porridges intended for use in infant feeding[16]. The calculated mean viscosities of samples containing plain/malted (PM samples), plain/fermented (PF samples) and plain/malted/fermented (PMF samples) sorghum flours were 2538 cP, 3216 cP and 2586 cP, respectively. Thus, samples containing plain/malted sorghum flours yielded the lowest mean final viscosity and hence the lowest dietary bulk; energy density in relation to viscosity is termed dietary bulk[17]. Some drawbacks of these samples, particularly sample PM (25:75), were that the porridges were slightly gritty, possibly due to the compact structure of the extrudate particles, too dark brown, had a bitter taste and a strong malt flavour compared with the other samples. Nevertheless, their low viscosities meant that there was flexibility for manipulating product consistency by increasing the solids concentration. This would also provide a simple and inexpensive means of increasing the product's nutrient density. Increased levels of malted four would however exacerbate the above-mentioned negative characteristics. There is thus a need to strike a balance between the negative and positive aspects that accompany increased malt levels. The significantly lower viscosities observed in samples containing plain/malted flours (compared to those containing plain and plain/fermented sorghum flours) may be attributed to the enzymatic breakdown of materials, particularly storage components such as starch and proteins within the grain during germination, into smaller, soluble and more usable forms for the growing grain [18,7]

DISCUSSION

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Of the many chemical changes that occur during germination, the one that has the greatest effect on viscosity is the conversion of starch by amylase enzymes into dextrins and maltose[7]. Since these products of starch hydrolysis do not gelatinize when cooked, the germination of grains can have a marked effect on the viscosity of starchy porridges. Malt is therefore an important ingredient in addressing the issue of dietary bulk of weaning foods required in meeting a growing infant's energy needs.

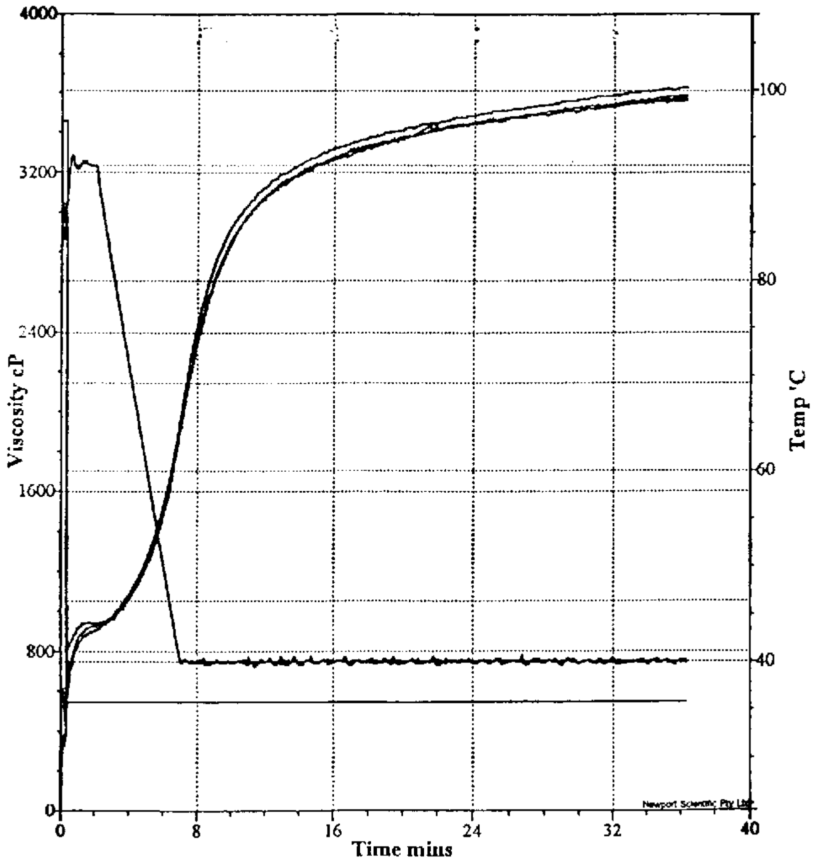

Fig. 1 Viscosity profiles of sorghum weaning porridges made by extruding dehulled plain (100%) sorghum flour (20%solids content – d.m.)

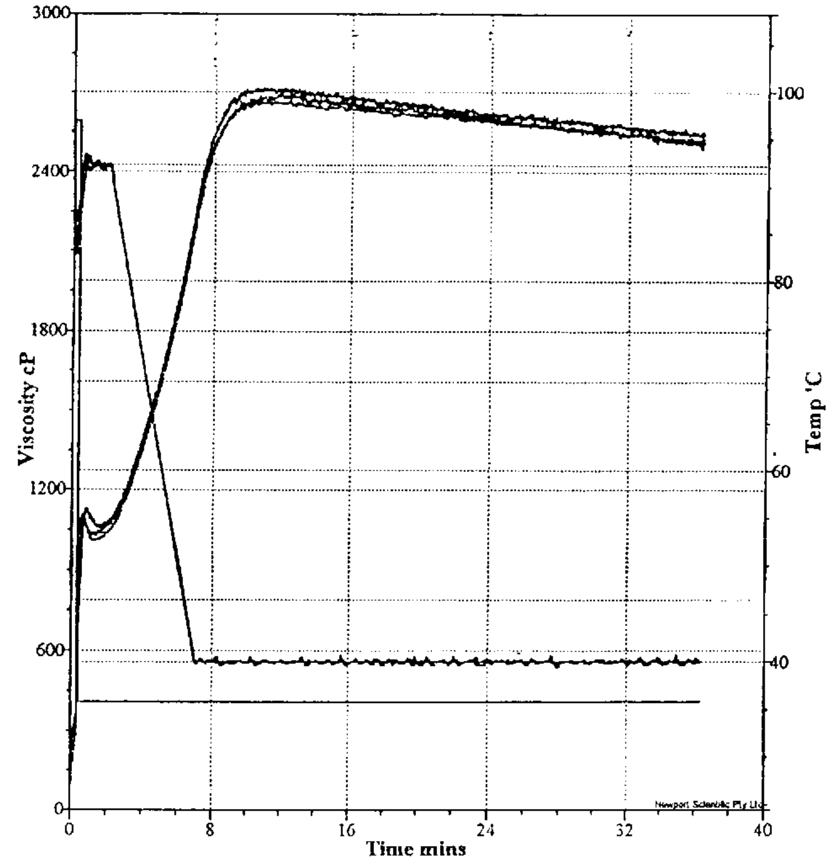

Fig. 2 Viscosity profiles of sorghum weaning porridges made by extruding a mixture of dehulled plain and malted sorghum flours [25:75] (20%solids content – d.m.)

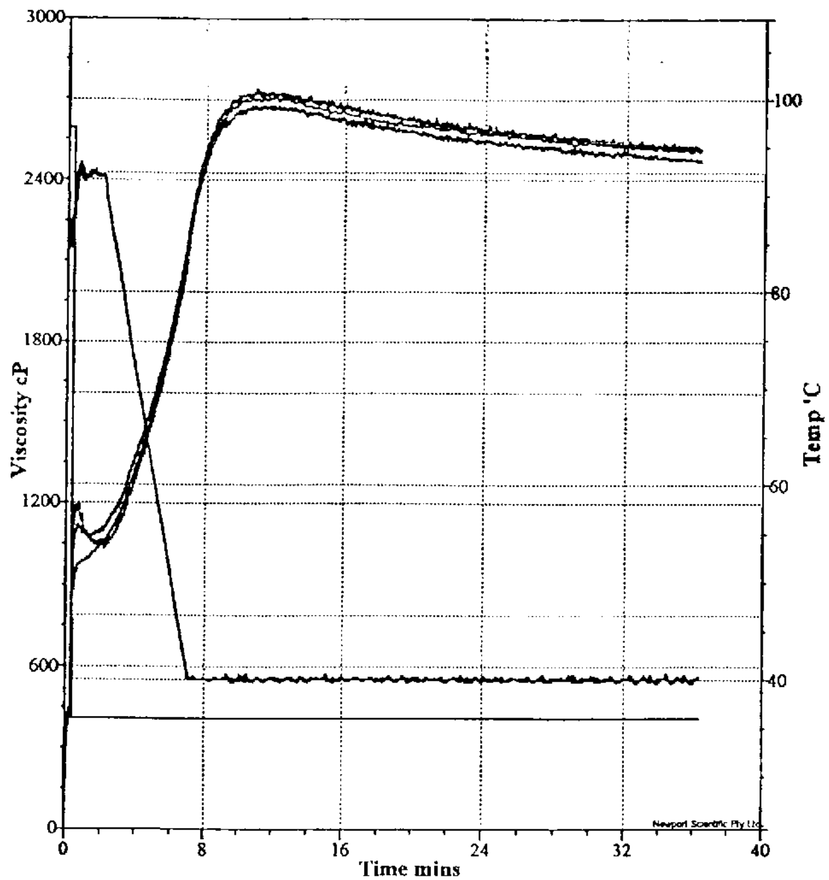

Fig. 3 Viscosity profiles of sorghum weaning porridges made by extruding a mixture of dehulled plain and malted sorghum flours [50:50] (20% solids content – d.m.)

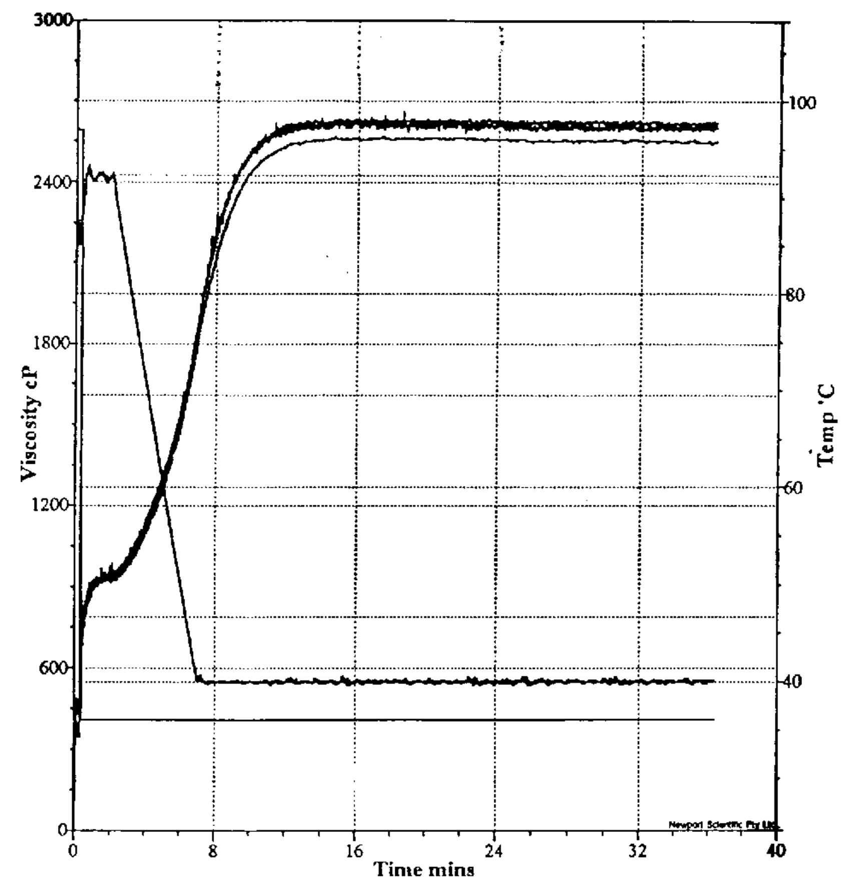

Fig. 4 Viscosity profiles of sorghum weaning porridges made by extruding a mixture of dehulled plain and malted sorghum flours [75:25] (20% solids content – d.m.)

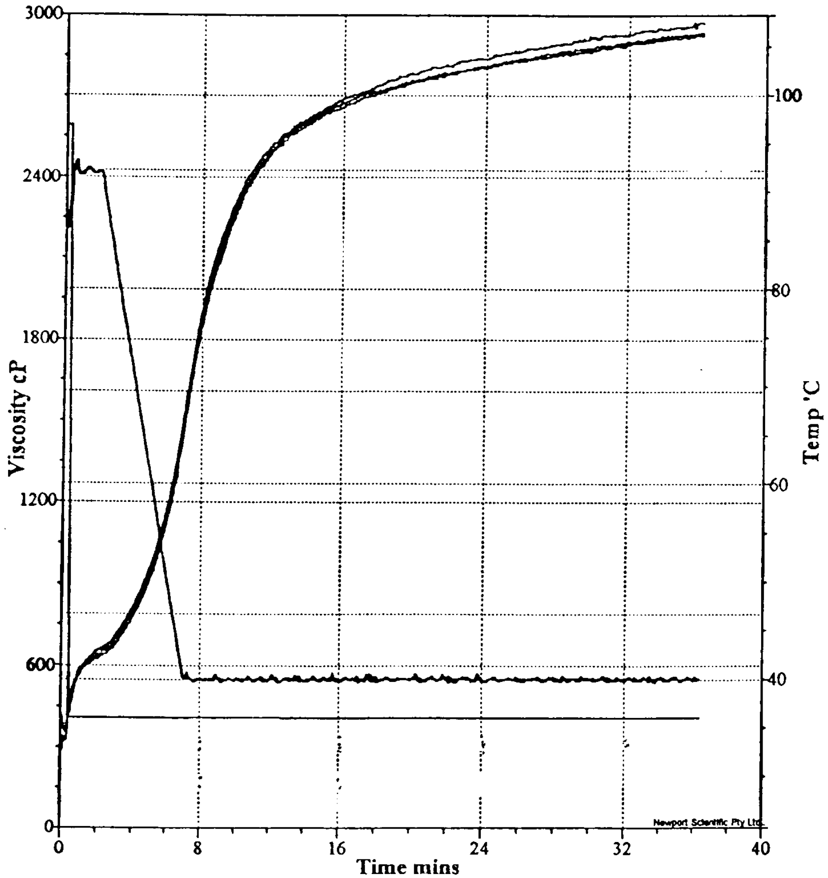

Fig. 5 Viscosity profiles of sorghum weaning porridges made by extruding a mixture of dehulled plain and fermented sorghum flours [25:75] (20%solids content – d.m.)

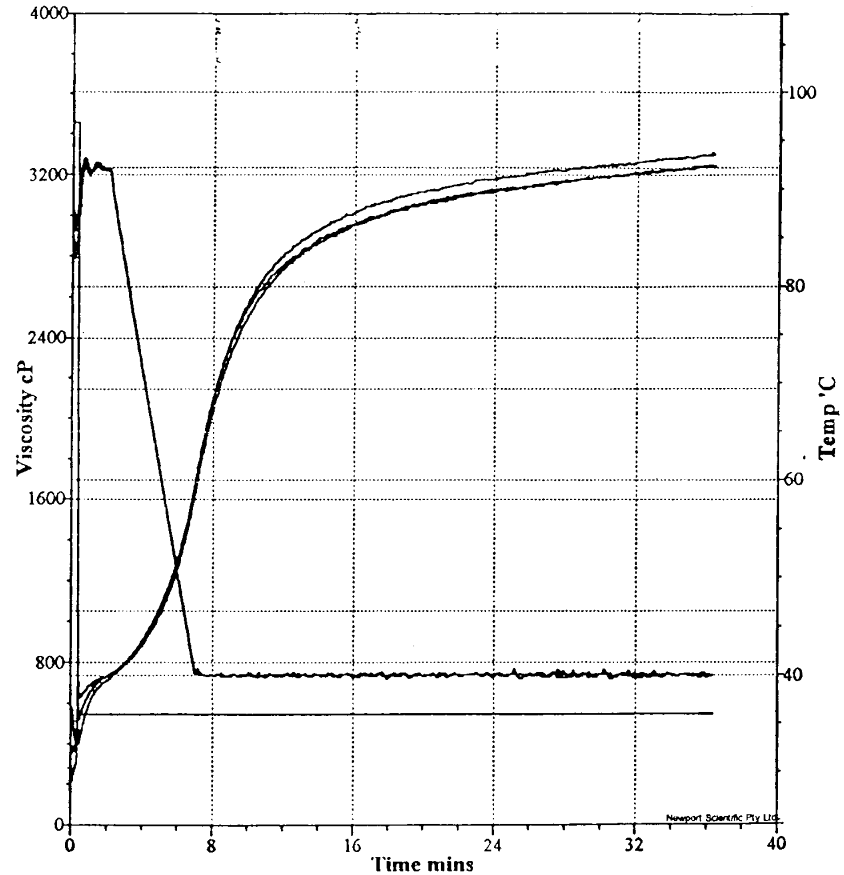

Fig. 6 Viscosity profiles of sorghum weaning porridges made by extruding a mixture of dehulled plain and fermented sorghum flours [50:50] (20%solids content – d.m.)

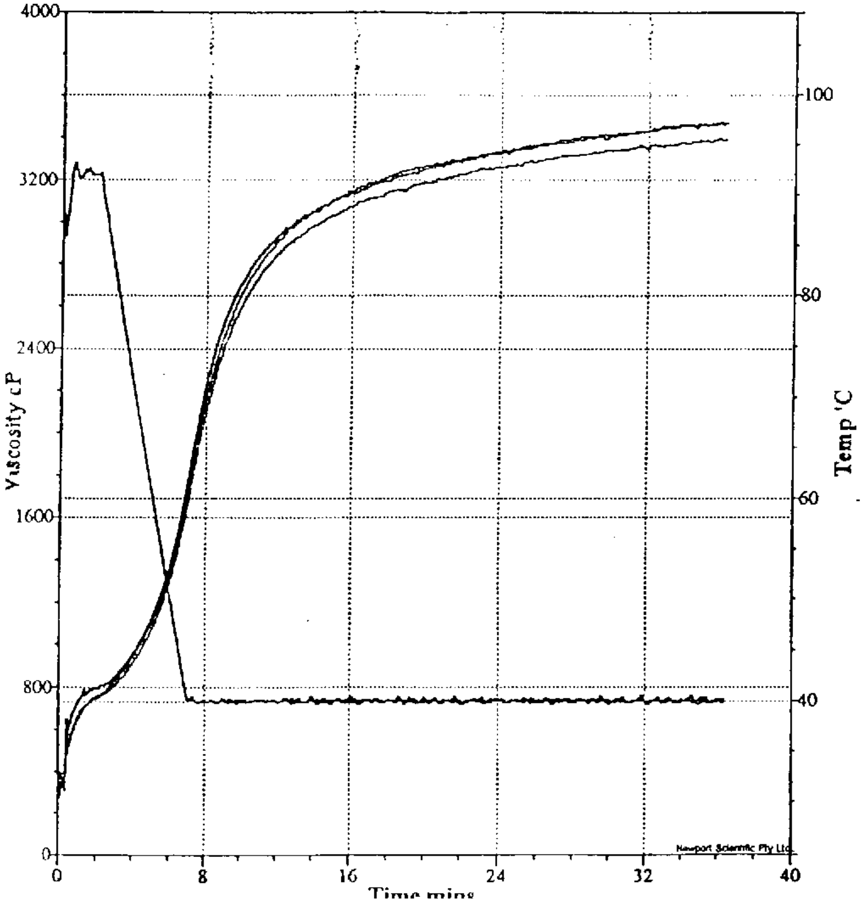

Fig. 7 Viscosity profiles of sorghum weaning porridges made by extruding a mixture of dehulled plain and fermented sorghum flours [75:25] (20%solids content – d.m.)

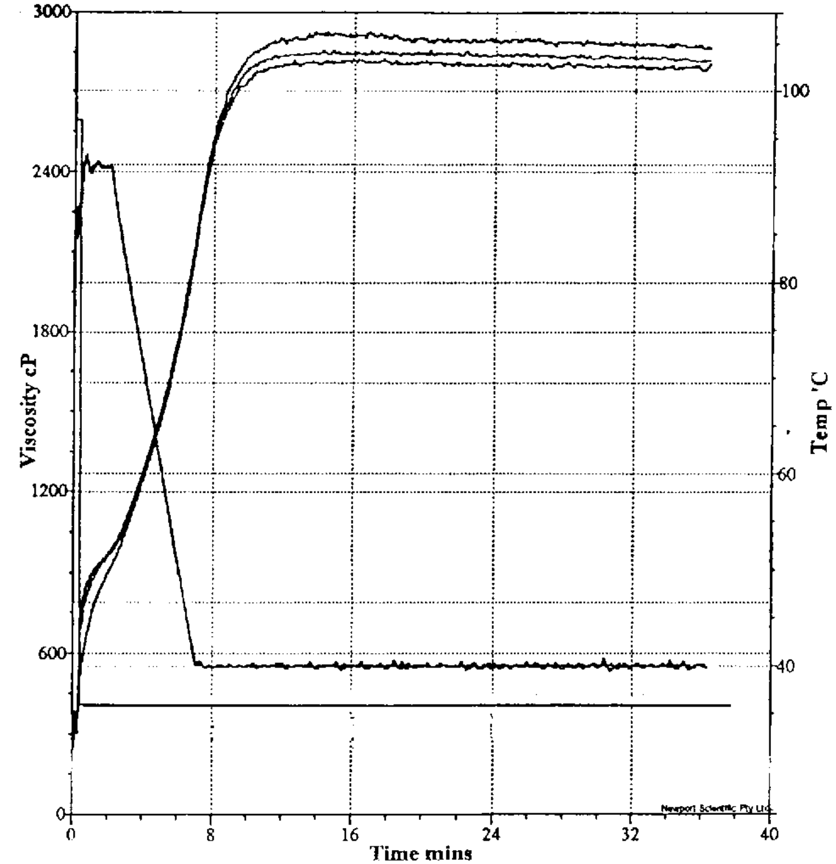

Fig. 8 Viscosity profiles of sorghum weaning porridges made by extruding a mixture of dehulled plain, malted and fermented sorghum flours [50:25:25] (20%solids content – d.m.)

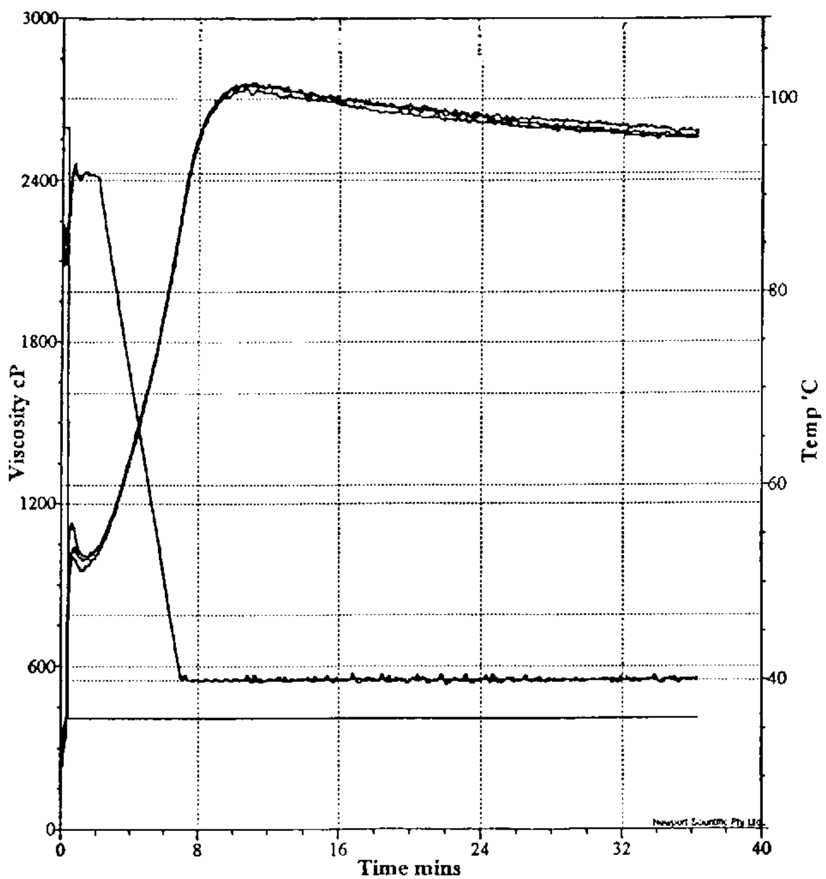

Fig. 9 Viscosity profiles of sorghum weaning porridges made by extruding a mixture of dehulled plain, malted and fermented sorghum flours [25:50:25] (20%solids content – d.m.)

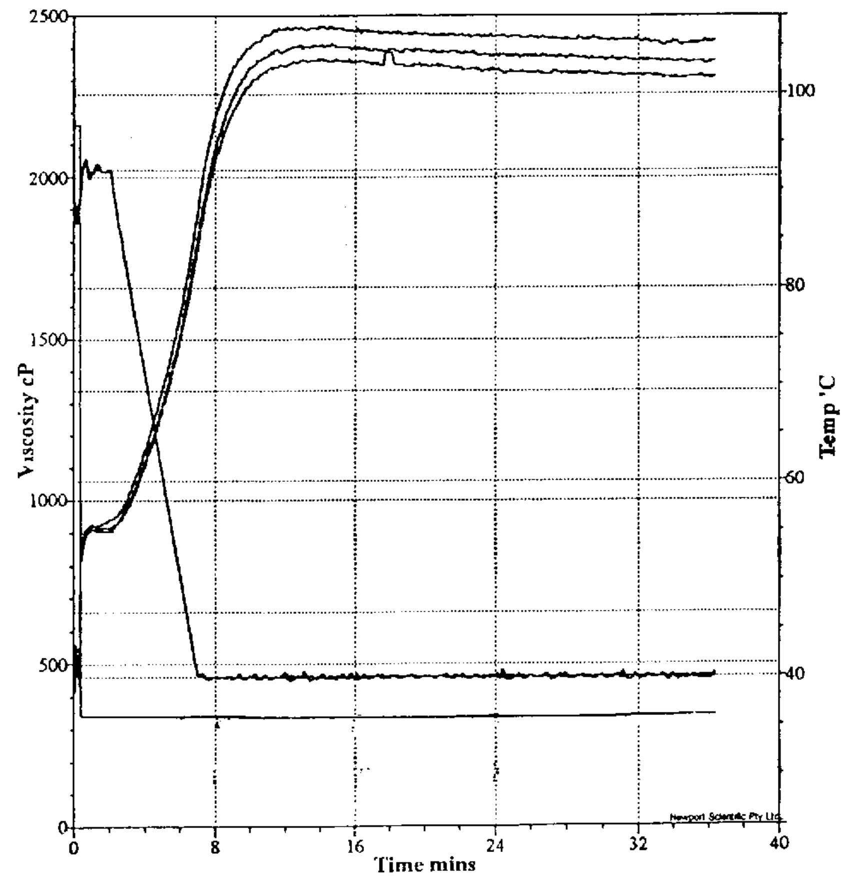

Fig. 10 Viscosity profiles of sorghum weaning porridges made by extruding a mixture of dehulled plain, malted and fermented sorghum flours [25:25:50] (20%solids content – d.m.)

This study clearly showed that with extruded sorghum weaning porridges, addition of fermented sorghum flour does cause reduction in viscosity, but not to the lower levels achieved by the addition of malt flour. The starter culture used in this study was obtained by a spontaneous fermentation of sorghum flour. Such fermentation normally involves souring by mixed cultures of yeast and lactobacilli[19]. Certain species of yeast have been reported to be amylolytic. An example is *Candida tropicalis,* which is able to grow on soluble starch without requiring previous hydrolysis since it possesses the enzyme (alpha-amylase) needed for the hydrolysis of starch[20]. Fermentation causes degradation of grain components, especially starch and soluble sugars, by both intrinsic grain enzymes and enzymes emanating from the microorganisms resulting in the formation of smaller compounds such as simple sugars[3]. In this way, fermentation enhances nutrient digestibilities and also causes a reduction in the viscosity of the fermented material.

CONCLUDING REMARKS

Evident from this study is the fact that it is possible to formulate and manufacture by extrusion cooking infant weaning foods of high nutrient density using combinations of plain, malted and fermented sorghum flours. Since some formulations had viscosities lower than 3000 cP, there was flexibility for manipulating the porridge consistencies by increasing the solids content. This means that higher nutrient densities could be achieved without compromising the bulk densities of the porridges. This therefore serves as a simple method of enhancing the energy density, protein quantity as well as intake of all the other nutrients needed for adequate child nutrition. The fact that the porridge made from the sample containing plain, malted and fermented sorghum flours in the ratios of 25:25:50 respectively exhibited the lowest viscosity suggests the possible existence of a synergistic effect between malted and fermented flours during extrusion.

In conclusion, it could be worthwhile investigating whether a sample containing, say, 25% plain, 20% malt and 55% fermented sorghum flours would have a lower viscosity than the lowest viscosity obtained in this study. There is also a need to optimise the whole production process, with particular emphasis on malting and the extrusion parameters. With regard to malting, it would be important to investigate whether use of sorghum malt flour with a higher DP than used in this study would further reduce the viscosities of the porridges.

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REFERENCES

1. Lorri, W.S.M. Nutritional and microbiological evaluation of fermented cereal weaning foods. Ph.D. thesis. Chalmers University of Technology, Göteborg, Sweden. (1993).
2. Cameron, H. & Hofvander, Y. Manual on Feeding Infants and Young Children. Oxford Medical Press, New York (1983) pp 7-71.
3. Chavan, J.K. & Kadam, S.S. Nutritional improvement of cereals by sprouting. *Critical Reviews in Food Science and Nutrition* **28** (1989) 401-437.

4. Chavan, J.K. & Kadam, S.S. Nutritional improvement of cereals by fermentation. *Critical Reviews in Food Science and Nutrition* **28** (1989) 349-400
5. Lechtig, A. & Srivastava, S. A strategy to improve weaning practices in Mozambique. In "Improving Young Child Feeding in Eastern and Southern Africa: Household Level Food Technology", (D. Alnwick, S. Moses & O.G. Schmidt, eds), International Development Research Centre, Ottawa, Canada (1988) pp 113-127.
6. Nout, M.J.R., Hautvast, J.G.A.J., Van der Haar, F., Marks, W.E.W. & Rombouts, F.M. Formulation and microbiological safety of cereal-based weaning foods. In "Improving Young Child Feeding in Eastern and Southern Africa: Household Level Food Technology", (D. Alnwick, S. Moses & O.G. Schmidt, eds), International Development Research Centre, Ottawa, Canada (1988) pp 245-260.
7. Ashworth, A. & Draper, A.,. The Potential of Traditional Technologies for Increasing the Energy Density of Weaning Foods. A Critical Review of Existing Knowledge with Particular Reference to Malting and Fermentation. WHO/CCD/EDP 92.4. Centre for Human Nutrition, London, UK. (1992) pp. 1-50.
8. Anderson, R.A., Conway, H.F., Pfeifer, V.F. & Griffin, E.L. Roll- and extrusion-cooking of grain sorghum grits. *Cereal Science Today* **14** (1969) 372-376.
9. Jansen, G.R. & Triblehorn, R.E. Effect of extrusion on calorie density of cereal and cereal/legume blends. In 'Special Report - Evaluation of Low Cost Extrusion Cookers for Use in LDCs'. Departments of Agriculture, Chemical Engineering and Food Science and Nutrition, Colorado State University. Fort Collins, CL. (1980) pp 1-19.
10. De Muelenaere, H.J.H. Extrusion: A first and third world tool. In 'Technology and the Consumer, Vol.1'. Proceedings of the SAAFoST Tenth Biennial Congress and a Cereal Science Symposium. Natal Tecknikon Printers, Durban, South Africa. (1989) pp. 22-42.
11. Likimani, T.A., Alvarez-Martinez, L. & Sofos, J.N. The effect of feed moisture and shear strain on destruction of *Bacillus globigii* spores during extrusion cooking. *Food Microbiologyl* **7** (1990) 3-11.
12. Wambugu, S.M. Malted and fermented sorghum as functional ingredients in extruded instant weaning porridges. M.Sc. thesis. University of Pretoria, South Africa (1999).
13. Colonna, P., Tayeb, J., & Mercier, C. Extrusion cooking of starch and starchy products. In "Extrusion Cooking", (C. Mercier, P. Linko & J.M. Harper, eds.), American Association of Cereal Chemists. St. Paul, MN (1989) pp 247-319.
14. Anderson, R.A., Conway, H.F., Pfeifer, V.F. & Griffin, E.L.,. Gelatinisation of corn grits by roll- and extrusion-cooking. *Cereal Science Today.* **14** (1969) 4-12.
15. Mercier, C. & Feillet, P. Modification of carbohydrate components by extrusion-cooking of cereal products. *Cereal Chemistry* **52** (1975) 283-297.
16. Mosha, A.C. & Svanberg, U. Preparation of weaning foods with high nutrient density using flour of germinated cereals. *Food and Nutrition Bulletin* **5** (1983) 10-14.
17. Griffith, L.D., Castell-Perez, M.E. & Griffith, M.E.,. Effects of blend and processing method on the nutritional quality of weaning foods made from selected cereals and legumes. *Cereal Chemistry* **75** (1998) 105-112.
18. Parvathy, K. & Sadasivam, S. Comparison of amylase activity and carbohydrate profile in germinating seeds of *Sertaria italica, Echinochloa frumentacea,* and *Panicum miliaceum*. *Cereal Chemistry* **9** (1982) 543-544.
19. Serna-Saldivar, S. & Rooney, L.W. Structure and chemistry of sorghum and millets. In "Sorghum and Millets: Chemistry and Technology", (D.A.V. Dendy, ed.), American Association of Cereal Chemists. St. Paul, MN. (1995) pp. 69-124.
20. Mlingi, N.L.V. Reducing dietary bulk in cassava-based weaning foods by fermentation. In "Improving Young Child Feeding in Eastern and Southern Africa:

Household Level Food Technology", (D. Alnwick, S. Moses & O.G. Schmidt eds.), International Development Research Centre, Ottawa, Canada. (1988) pp 208-219