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Original article

Effect of processing technique on energy density and viscosity of cooking banana: implication for weaning foods in Uganda

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Abstract The type and quality of weaning food plays a vital role in the growth and development of children. The high rates of malnutrition reported in banana consuming areas of Uganda reveal the bulkiness and high viscosity of the predominant banana-based weaning foods. The objective was to determine the impact of processing technique on energy density and viscosity of cooking banana. Part of the unprocessed dried slices was milled into fine flour and the rest extruded. Pre-gelatinised banana flour was produced using a modified earlier method. Nutrient and energy composition of the flours were determined using standard methods. Data were subjected to one-way ANOVA/least significant difference test and *t*-test using GenStat 5 Release 3.2. Pre-gelatinisation and extrusion cooking significantly raised energy content of banana significant impact on its viscosity but with extrusion cooking achieving better results. Extrusion cooking and pre-gelatinisation increase the energy content of cooking bananas and significantly reduces its bulkiness. Soybean and simsim addition will improve protein quality and quantity of banana-based weaning products.

Keywords Bulk, extrusion, protein energy malnutrition, pre-gelatinisation, viscosity, weaning.

Introduction

The capacity of a weaning diet to meet the protein and energy requirements of infants depends on its nutritional quality as well as its dietary bulkiness (Mosha *et al.*, 2000; Osundahunsi & Aworth, 2002; Sajilata *et al.*, 2002; Thathola & Srivastava, 2002; Mosha & Vicent, 2004). In the event of high banana production and consumption especially in most parts of Uganda, high incidences of protein energy malnutrition (PEM) among infants born in the '*matooke*' (banana) dietary-dependent cultures have been reported (Mafara, 1994; Kikafunda *et al.*, 1998). Cassava and other root tubers are among other foods offered during weaning period (FAO, 1990, 2001). It was noted that weaning, a time when the child needs high energy and about twice as much protein in relation to body weight as do adults, is compromised in Uganda by weaning diets of low energy density and protein quality and quantity (Gibson *et al.*, 1998; Kikafunda *et al.*, 1998; Tumwine & Barugahare, 2002).

Weaning foods need to be rich in energy and nutrients since beyond six months of age, children cannot get enough energy and nutrients from breast milk alone (Savage & Burgess, 1993). Therefore to address this problem, plant protein rich sources, such as soybean and simsim need to be added to starch-based diets whose bulkiness has been reduced through application of simple technologies. Most of the weaning foods used in Uganda are starch staples containing high fibre making them difficult to digest and meet the nutrition requirement of infants. Cooking banana (*matooke*), one of the most used weaning foods in Uganda, has low energy density because of the high fibre and viscosity (bulkiness) and there are no documented attempts to reduce its inherent bulkiness. It is in this context that studies aimed at identifying and propagating simple traditional methods of reducing the bulkiness of starch-based diets and increasing their energy density require considerable attention.

The weaning diets of Ugandan children in most cultures are not only bulky but are also poor in certain nutrients (Uganda Demographic and Health Survey (UDHS), 2000/2001). This reveals a need for greater emphasis on development of weaning products of high energy density and low viscosity without compromising the sensory quality of these products. Most information about Uganda weaning diets is anecdotal. More effort needs to be invested in studies that more clearly and precisely define energy density and protein quality of weaning diets. Literature shows that banana bulkiness

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could be effectively overcome through extrusion cooking and pre-gelatinisation (Muranga, 1992). However, nothing is known regarding which method is the most efficient.

The rehabilitation of severely malnourished children at Mwanamugimu unit in Uganda has employed preparation of protein rich sources comprising simsim and legume or nut mixture to complement mashed staples particularly *'matooke'* prepared in the traditional way. Given that these children need several servings in a day for adequate catch-up growth, these efforts have been hindered by the amount of labour involved in the preparation of these protein rich mixtures.

This research work was therefore undertaken to study the effect of processing technique on energy density of cooking banana and evaluate the impact of processing technique on its viscosity.

Materials and methods

The study was conducted at the Department of Food Science and Technology laboratory, Makerere University in Kampala, Uganda where the dryer was located. However, determination of flour pasting characteristics was done at Bundesforschungsanstalt für Ernährung und Lebensmittel (BFEL), Detmold, Germany.

Preparation of flours

Unprocessed banana flour (dried raw banana slices) was produced by peeling and slicing of the raw banana fruit (AAA-EA) using stainless steel knives into slices of half an inch (Fig. 1). The slices were placed in a 0.2% solution of sodium metabisulphite (w/v) for about 5 min to prevent browning and then dried in an electrical drier at 60 °C for about 12 h. Part of the unprocessed dried slices was milled into fine flour and the rest were extruded using a single screw extruder. Extrusion was effected through a ZSK 40 Werner and pfleider co-rotating twin extruder, Continua 58 whose processing barrel consisted of six separately controlled cylinder hot zones at a die temperature of 140 °C (Muranga, 1998). Pre-gelatinised banana flour was produced using an earlier method but with modification to suit the traditional banana cooking process of matooke (Muranga & Haase, 1997). Bananas were washed and cooked till tender in a pressure cooker at a temperature ranging between 98–100 °C for 5 min. This time was adequate to sufficiently loosen the banana peel, allowing hand stripping off of the peels. After cooling the bananas fingers under tap water (23 °C), the peels were removed and sliced into slices of half an inch. The slices were arranged on trays as above and dried in an electrical drier at 60 °C for about 12 h.

Soybean (*Glycine max*) flour was obtained by dehulling dry soybeans and extruding using the single screw extruder to obtain extruded material. Simsim (*Sesame indicum*) flour was obtained by soaking simsim seeds in hot 0.6% sodium hydroxide for 1 min (w/v). The seeds were then washed with in excess tap water at 23 °C, scrubbed to remove the hull and dried in hot air oven (size 2, SG93/B6/95 Gallenkamp, UK) at 60 °C for 12 h. The dry dehulled seeds were roasted in an oven at 170 °C for 25 min, and then pounded to obtain flour of a roasted simsim flavour.

Figure 1 Spreading of banana slices on a tray before loading into the dryer.

Determination of viscosity

Pasting viscosity of banana, soybean and simsim flours was determined using the Rapid Visco Analyser (RVA), Thermocline version 2.0 new point scientific PTY Ltd 1992 NSW Australia. This was done in Germany and heating was done at 50–95 °C. The key pasting parameters determined were peak, trough and end viscosities.

Proximate analysis

Moisture, crude fat, fibre, crude protein, ash and energy composition of the flours were determined using standard methods. Moisture was determined by AOAC (1997) method 4.1.03. Ash determination was by dry ashing at 450 °C (AOAC, 1990), whereas crude fat by Soxhlet extraction (Harris, 1970). Gross energy content was determined using a bomb calorimeter (AOAC, 1990).

Data analysis

Data for nutrient and energy composition was subjected to one-way analysis of variance (ANOVA) using GenStat 5

Release 3.2 and means were separated by least significant difference (LSD) test at 5% probability level to assess whether there were significant ($P < 0.05$) differences between unprocessed and processed banana flours. Viscosity data were compared using *t*-test.

Results

Proximate analysis

The average nutritional and energy content of the banana flours are shown in Table 1. The protein and energy content of pre-gelatinised and extruded banana were both significantly higher than that of unprocessed banana. However, extruded banana exhibited significantly higher energy content than pre-gelatinised banana, showing that though both treatments increase energy density of unprocessed banana (dried raw banana with out any treatment), extrusion cooking is more effective. The low crude fibre content in unprocessed and extruded bananas compared to pre-gelatinised banana may be attributed to loss of fibre in banana peel during peeling and changes in chemical properties of banana during extrusion respectively (Hui, 1992; Muranga & Mavenjina, 2001). It was noted that extrusion cooking which is a high temperature short-time process, changes the physical and chemical properties of food (Hui, 1992).

The existence of a significant difference ($P < 0.05$) in gross energy content of pre-gelatinised and extruded banana is evidence that pre-gelatinisation and extrusion cooking are effective processing technologies in reducing bulkiness of cooking banana, thus enhancing its energy density. The energy content of extruded banana was, however, significantly higher than that of pre-gelatinised banana implying that extrusion cooking is an efficient processing technology in reducing bulkiness of cooking banana.

Table 2 shows the average nutritional and energy content of processed soybean and simsim flours. The fat content of simsim (62.76%) was in the range reported by Salunkhe *et al.* (1992). However, the crude fibre and ash contents were slightly higher than in original samples as by Salunkhe *et al.* (1992) while moisture (1.51%) and protein content (20.80%) were lower than those reported by Salunkhe *et al.* (1992), of 4.1% and 22.1% respectively, because simsim was subjected to roasting at 170°C for about 25 min before grinding. This possibly reduced moisture content of simsim and caused loss of some proteins. The protein (36.97%), moisture (5.11%), fat (21.07%), ash (5.80%) and fibre (2.10%) contents of soybean, were in the ranges reported by Salunkhe *et al.* (1992).

Pasting viscosity of flours

The results showed pre-gelatinised and extruded flours as the most restricted in their swelling (Table 3). Muranga (1998) noted that the peak viscosity values are an indicator of the ease of swelling by the starch granules with a low peak value reflecting restricted swelling (reduced bulk). Extrusion, however, was found to be the preeminent processing technology in reducing bulk and consequently increasing energy density of the processed flour. Trough and end viscosities also showed a similar trend. Soy and simsim flours exhibited zero viscosities.

Table 1 Nutrient and energy content of banana flours per 100 g

	Composition					
Flour	**Moisture content (g)**	**Crude fat (g)**	**Crude protein (g)**	**Gross energy (kcal)**	**Fibre (g)**	**Total ash (g)**
Unprocessed Banana	8.06^{c}	0.72^{a}	4.05^{a}	365.00^{a}	2.88^{a}	3.36^{a}
Pre-gelatinised Banana	7.00^{a}	0.80^{b}	5.07^{b}	372.67^{b}	3.57^{b}	4.30^{b}
Extruded Banana	7.49^{b}	0.83^{b}	5.76^{c}	404.33^{c}	2.87^{a}	5.76^{c}
LSD	0.18	0.02	0.08	1.88	0.02	0.02

Means within a column with the same alphabets (superscript in position) are not significantly different ($P < 0.05$).

Table 2 Nutrient and energy content of processed soybean and simsim per 100 g

	Composition					
Flour	**Moisture content (g)**	**Crude fat (g)**	**Crude protein (g)**	**Gross energy (kcal)**	**Fibre (g)**	**Total ash (g)**
Extruded Soybean	5.11^{b}	21.07^{a}	36.97^{b}	521.67^{a}	2.10^{a}	5.80^{b}
Dehulled simsim	1.51^{a}	62.76^{b}	20.80^{a}	740.00^{b}	6.05^{b}	4.40^{a}
LSD	0.17	0.44	0.04	1.85	0.03	1.26

Means within a column with the same alphabets (superscript in position) are not significantly different ($P < 0.05$).

Table 3 Pasting viscosity of banana flours using RVA

	Viscosity (RVU units)		
Code	Peak	Trough	End viscosity
Unprocessed banana	330.37	196.50	255.50
Pre-gelatinised Banana	106.10	92.00	149.00
Extruded banana	16.00	0.00	2.00
t	3.23	3.37	3.69
P-value	0.012	0.010	0.006

Discussion

The prevalence of stunting in children below 5 years in East Africa averages about 48% (Girma & Timotiows, 2002), which is among the highest in the world. Malnutrition in children results in growth retardation, limited intellectual abilities that diminish their working capacity during adulthood, decreased resistance to disease and infections and ultimately, ill health and death (Kikafunda *et al.*, 1998; Ssewanyana, 2003). Health costs to the nation and the families plus the time the mother spends attending to a sick child are enormous. In Uganda, infant mortality rates (IMR) and childhood mortality rates (CMR) are high, estimated at 88 and 152 deaths, respectively per 1000 live births (Uganda Demographic Health Survey (UDHS), 2000/2001). According to Uganda Bureau of Statistics (UBOS), ORC Macro and USAID. (2001), 34% of all deaths that occur before 5 years of age in Uganda are related to malnutrition (moderate–severe malnutrition).

Findings from the Uganda Demographic and Health Survey (2000/2001) showed that 39% of children under 5 years of age (0–59 months) are chronically malnourished (stunted). The proportion of children who are stunted is almost 20 times the level expected in a healthy and well-nourished population. Acute malnutrition manifested by wasting results in a child being too thin for his or her height. It affects 4% of children, which is twice the level expected in a healthy population. Twenty-three percent of children under 5 years of age are underweight for their age, more than 11 times the level expected in a healthy, well-nourished population.

Feeding practices, such as time of introduction and type of complementary food, quality and quantity of foods given, have been identified as one of the most important factors for the child's nutritional status. Kikafunda *et al.* (1998) found that children who were fed foods of low energy density (kcal/100 g dry matter) had greater incidence of stunting. Another study among children in Kenya, aged 12–36 months, found that dietary diversity was strongly and consistently related to nutritional status and early complementation with starchy gruels was associated with stunting (Onyango *et al.*, 1998).

A study in Uganda further revealed that while breastfeeding was universal at birth, early weaning with watery, energy and nutrient poor staples was widespread in rural area (Kikafunda *et al.*, 2003). It was noted that weaning foods were dominated by the green cooked banana (*matooke*) which is known to be bulky with low nutrient content. In the same study, consumption of animal protein, fruit and vegetables was found to be very low among children, a possible risk factor for the high levels of malnutrition among children under 5 years. Mafara (1994), noted that the high incidence of protein energy malnutrition among infants weaned on cooking banana are attributed to the bulkiness of the protein deficient '*matooke*' which makes it difficult for children to eat enough to satisfy their daily nutrient and energy requirements. Findings of the current study revealed that energy density of gruels prepared for infant feeding can therefore be increased by reduction of their viscosity through extrusion cooking or pre-gelatinisation. Savage & Burgess (1993) noted that the bulk problem can be overcome by changing the starch through pre-gelatinisation and enriching the pre-gelatinised food.

It has been shown that extrusion processing of bananas results in greater retention of aroma and better control over starch gelatinisation (Muranga, 1998 and Muranga & Mavenjina, 2001). Extrusion cooking is quite effective in modifying the starch granules because of the action of high temperatures at high pressure. Modification of the starch granules reduces their water binding and gelatinisation capacity thus reducing viscosity (Kikafunda, 1996). Similar to earlier studies on starch staples, the current study revealed that extrusion cooking is a more efficient method to achieve banana starch modification compared to pre-gelatinisation.

Hui (1992) and Muranga (1998) concluded that, there is degradation of the starch macromolecules after extrusion cooking. The low viscosity of the extruded banana flours and its blends are therefore attributed to macromolecular degradation and expansion of banana starch. It was reported that starch molecular degradation is mainly a consequence of low moisture content and high shear resulting from high screw speed (Muranga, 1998). However, it should be noted that other than starch gelatinisation and protein denaturation, many other changes occur during the extrusion process, such as non-enzymic browning affecting the quality of the final product (Hui, 1992).

Therefore, by reducing the extent to which pastes thicken, extrusion cooking and pre-gelatinisation facilitate increase in energy and nutrient density, since higher levels of solids may be added during the preparation of gruels (Colonna *et al.*, 1984; Opendi & Muyonga, 1999). It was noted that starch pre-gelatinisation reduces the ability of starch molecules to swell, which is part of the mechanism behind viscosity increase during heating of starchy pastes.

Studies show that legumes complement each other so that the nutritional value of the mixture is greater than that of either ingredient (Muranga, 1992; Lusas & Riaz, 1995; Tchango, 1995; Malleshi *et al.*, 1996; Mosha & Vicent, 2004). Incorporation of soybean and simsim flours in banana-based flour will improve the nutritive value in particular methionine and lysine content to that which will be of significance in weaning diets. These formulations will address questions on what to wean with, an issue which though of great importance in Uganda, has not received adequate scientific attention.

Conclusion

Pre-gelatinisation and extrusion cooking significantly raised energy content of unprocessed banana (3.65 kcal g^{-1}) to 3.73 kcal g^{-1} and 4.04 kcal g^{-1} respectively, however, extrusion was more efficient. Our study reveals that extrusion cooking can be used to improve the energy content of cooking bananas and also to reduce significantly its bulkiness accordingly, improving the energy and nutrient availability of weaning foods in banana eating cultures like Uganda. Shelf-life and acceptability trials of the extruded banana samples and incorporation of protein rich flours in particular those of simsim and soybean to enhance protein quality and quantity of the final product is recommended.

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References

AOAC (Association of Analytical Chemists) (1990). *Official Methods of Analysis*. 15th edn. Arlington, Virginia, USA: AOAC Inc.

AOAC (Association of Analytical Chemists) (1997). *Official Methods of Analysis*. 16th edn. Maryland, USA: AOAC International: Gaithersberg.

Colonna, P., Doublier, J.L., Melcoin, J.P., de Monredon, F. & Mercier, C. (1984). Extrusion cooking and drum drying of wheat starch. Physical and macromolecular modifications. *Cereal Chemistry*, **62**, 538–543.

FAO (1990). *Roots, Tubers, Plantains and Bananas in Human Nutrition. FAO Food and Nutrition Series*. Rome: FAO, NO. 24: 10, 21, 41,102

FAO (2001). *Targeting for Nutrition Improvement*. FAO, Rome, 55, 63.

Gibson, R.S., Ferguson, E.L., Lehrfeld, J. (1998). Complementary foods for infant feeding in developing countries: their nutrient adequacy and improvement. *European Journal of Clinical Nutrition*, **52**, 764–770.

Girma, W. & Timotiows, G. (2002). *Determinants of Nutritional Status of Women and Children in Ethiopia*. Calverton, Maryland, USA: ORC Macro.

Harris, L.E. (1970). *Nutrition Research Technique for Domestic and Wild Animals*. **Vol. 1.** USA: Animal Science Department, Utah State University, Logon. Gallenkamp autobomb Automatic Adiabatic bomb calorimeter CBA 301 series manual.

Hui, Y.H. (1992). *Encyclopedia of Food Science and Technology*. **Vol. 3**, Pp. 2188. New York, NY: John Wiley & Sons, Inc.

Kikafunda, K.J. (1996). *Dietary Risk Factors for Childhood Malnutrition in Uganda. PhD Thesis Submitted to the University of Reading*. UK: Department of Food science and Technology.

Kikafunda, J.K., Walker, A.F., Collett, D. & Tumwine, J.K. (1998). Risk factors for early childhood malnutrition in Uganda. *Pediatrics*, **102**, 45–53.

Kikafunda, J.K., Walker, A.F. & Tumwine, J.K. (2003). Weaning foods and practices in Central Uganda: a cross-sectional study. *African Journal of Food, Agriculture, Nutrition and Development*, **3** [www.bioline.org.br/abstract?id = nd03012&lang = en].

Lusas, E.W. & Riaz, M.N. (1995). Soy protein products: processing and use. *Journal of Nutrition*, **125**, 573–580.

Mafara, G.R. (1994). Evaluation of traditional production methods and composition of bananas. *Production in Uganda*, **14**, 14.

Malleshi, N.G., Hadimani, N.A., Chinnaswamy, R. & Klopfenstein, C.F. (1996). Physical and nutritional qualities of extruded weaning foods containing sorghum, pearl millet or finger millet blended with mung beans and nonfat dried milk. *Plant Foods and Human Nutrition*, **49**, 181–189.

Mosha, T.C. & Vicent, M.M. (2004). Nutritional value and acceptability of homemade maize/sorghum-based weaning mixtures supplemented with rojo bean flour, ground sardines and peanut paste. *International Journal of Food Science and Nutrition*, **55**, 301–315.

Mosha, T.C.E., Laswai, H.S. & Tetens, I. (2000). Nutritional composition and micronutrient status of home made and commercial weaning foods consumed in Tanzania. *Plant Foods and Human Nutrition*, **55**, 185–205.

Muranga, F.I. (1992). Incorporation of soybean into local diets. *Proceedings of the First Workshop on Soybean Production and Utilization Held at Mukono District Farm Institute on 2nd–6th March*. Kampala: Uganda.

Muranga, F.I. (1998). *Composition and Physico-Chemical Characteristics of Starches of Different Banana Varieties*. Pp. 2, 3, 13, 14, 25, 76. Kampala, Uganda: PhD Thesis submitted to Department of Biochemistry, Makerere University.

Muranga, F.I. & Haase, N.U. (1997). *Characteristics of Dried Matooke Flours*. Det Mold, Germany.

Muranga, F.I. & Mavenjina, M.S. (2001). *Comparative Evaluation of Banana-Based Weaning Foods Processed Using Different Techniques*. Kampala, Uganda: Department of Food Science and Technology, Makerere University.

Onyango, A., Koski, K.G. & Tucker, K.L. (1998). Food diversity versus breastfeeding choice in determining anthropometric status in rural Kenyan toddlers. *International Journal of Epidemiology*, **27**, 484–489.

Opendi, S. & Muyonga, J.H. (1999). Effect of processing on nutritional quality of finger millet-cowpea formulations. *MUARIK Bulletin*, **2**, 27–33.

Osundahunsi, O.F. & Aworth, O.C. (2002). A preliminary study on the use of tempe-based formula as a weaning diet in Nigeria. *Plant Foods and Human Nutrition*, **57**, 365–376.

Sajilata, G., Singhal, R.S. & Kulkarni, P.R. (2002). Weaning foods: a review of the Indian experience. *Food and Nutrition Bulletin*, **23**, 208–226.

Salunkhe, D.K., Chavan, J.K., Adsule, R.N. & Kadam, S.S. (1992). *World oil Seeds; Chemistry, Technology and Utilisation*. Pp. 11–40, 373–394. New York: Van Nostrand Reinhold.

Savage, F.K. & Burgess, A. (1993). *Nutrition for Developing Countries*. 2nd edn. Pp. 124–127, 209. Oxford: Oxford University Press.

Ssewanyana, S.N. (2003). *Food Security and Child Nutrition Status Among Urban Poor Households in Uganda: Implications for Poverty Alleviation*. AERC Research Paper 130, African Economic Research Consortium, Nairobi. © 2003, African Economic Research Consortium. Pp 2, 3, 6, 54–57.

Tchango, J. (1995). The nutritive quality of maize-soybean (70:30) tempe flour. *Plant Foods and Human Nutrition*, **47**, 319–326.

Thathola, A. & Srivastava, S. (2002). Physicochemical properties and nutritional traits of millet-based weaning food suitable for infants of the Kumaon hills, Northern India. *Asian Pacific Journal of Clinical Nutrition*, **11**, 28–32.

Tumwine, J.K. & Barugahare, W. (2002). Nutrition status of children in Kasese district at the Uganda-Congo border. *East African Medical Journal*, **79**, 427–434.

Uganda Bureau of Statistics (UBOS), ORC Macro and USAID (2001). *Nutrition of Young Children and Mothers in Uganda African Nutrition Chart Books*. Pp. 1–74. Maryland, USA: ORC macro, Calverton.

Uganda Demographic Health Survey (UDHS) (2000/2001). *Uganda Bureau of Statistics, Entebbe*. Pp. 154, 155. Maryland, USA: Uganda and ORC Macro Calverton.