

58 Sweetpotato-based Formulation: An Alternative Food Blend for Complementary Feeding

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Abstract

In an effort to reduce the prevalence of protein-energy malnutrition among older infants, cereal-legume blends are being promoted as suitable complementary foods instead of cereal-only porridges. An example of such blend is Weanimix, which is a blend of non-dehulled maize, groundnut and non-dehulled soybean/cowpea. Although Weanimix has adequate protein and energy densities, it contains a significant level of phytate (an antinutrient that reduces iron, zinc and calcium bioavailability) and virtually no β -carotene (vitamin A precursor) when white maize is used for processing. Additionally, cereal-based infant foods form a very thick porridge that requires dilution with water to get the desirable viscosity, leading to 'energy and nutrient thinning' (i.e. reduction of energy and nutrient densities). This chapter summarizes the potential of an alternative complementary food formulated from sweetpotato (denoted as ComFa) using both household- and industrial-level processing methods. Both ComFa formulations (home-based and industrial-level) and Weanimix (prepared for comparison) met the stipulated energy and fat values specified in the Codex Standards. However, the protein content of the industrial ComFa formulations (extrusion-cooked ComFa and roller-dried ComFa) was lower by 17%, but the oven-toasted ComFa (household-level formulation) and Weanimix met the protein specification. The phytate content in all the ComFa formulations was approximately a quarter of the level of 0.80 g/100 g in the Weanimix. Only the sweetpotato-based infant foods contained measurable levels of β -carotene, resulting in significantly higher vitamin A content of the oven-toasted ComFa compared with enriched Weanimix (28.73 versus 1.20 μ g retinol equivalents/100 kcal). On average, sweetpotato-based formulations were higher in maltose (26 times), sucrose (five times), free glucose (19 times) and fructose (seven times) than levels in enriched Weanimix, but the ComFa formulations contained significantly less starch (10–13 versus 47 g/100 g). The high simple sugar and low starch levels in the ComFa formulations could explain the lower apparent viscosity (nine-, 13- and 20-times, for peak, 'consume' and final viscosities, respectively), higher water solubility index (seven times), and higher consumer acceptance compared with the maize-based formulation. On the basis of the compositional, functional and sensory findings of this study, the sweetpotato-based formulations have significant advantages as a complementary food compared with Weanimix due to the low level of phytate, the high levels of endogenous β -carotene and low viscosity.

Keywords: carotene, complementary/infant food, Ghana, maize, phytate, sweetpotato, vitamin A

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58.1 Introduction

Chronic vitamin A, zinc and iron deficiencies during early childhood may increase susceptibility to infections, cause stunted growth or blindness and may have irreversible effects on cognitive development (Grantham-McGregor *et al.*, 2007; Black *et al.*, 2008). Nutritional deficiencies during childhood limit an individual from achieving his/her full potential during adulthood, and have been associated with the intergenerational transmission of poverty in low-income countries (Grantham-McGregor *et al.*, 2007; Victora *et al.*, 2008; Atinmo *et al.*, 2009).

Vitamin A deficiency (VAD) among children under 5 years in sub-Saharan Africa (SSA) remains unacceptably high (44%), second to South-east Asia (50%), compared with the worldwide occurrence of 33% (WHO, 2009). Anaemia is similarly a worldwide public health problem. None the less, prevalence of anaemia (defined as haemoglobin concentration below 110 g/L) among infants and young children from 6 months old to 5 years old, is highest in Africa (68%) and South-east Asia (66%) compared with a global occurrence of 47% (de Benoist *et al.*, 2008). The main causative factors for iron deficiency anaemia include low iron intake and poor bio-availability due to diets high in phytate or phenolic compounds (Hurrell and Egli, 2010).

In SSA, complementary foods for infants and young children are mainly prepared from cereals or legumes (Gibbs *et al.*, 2011), and have been associated with VAD because the widely used white maize, and legumes are devoid or low in β -carotene/provitamin A (Lartey *et al.*, 1998; Dewey and Brown, 2003; Nuss and Tanumihardjo, 2010). Compounding the low provitamin A levels, is the high concentration of phytate in cereal-legume blends, limiting the bio-availability of essential micronutrients including iron (Gibson *et al.*, 2010). The limitations of some of the suggestions to reduce the level of phytate in complementary foods have been discussed elsewhere (Amagloh *et al.*, 2012c).

As well as the low vitamin A and high phytate contents of cereal-based blends, another issue of nutritional concern is the high viscous porridge formed when prepared from

unmalted cereals (Moshia and Svanberg, 1983, 1990). Suitable viscosity of cereal-based porridge for infants is obtained by dilution with water, leading to 'energy and nutrient thinning' (Amagloh *et al.*, 2013b), that is the reduction of energy and nutrient densities (Moshia and Svanberg, 1983, 1990; Kikafunda *et al.*, 1997).

Considering the nutritional issues mentioned above with regards to cereal-based complementary foods, we proposed sweetpotato-based (ComFa) formulations that could be prepared as a household- or an industrial-level product (Amagloh *et al.*, 2012c). Sweetpotato is: (i) suited to the tropical conditions prevailing in SSA (Padmaja, 2009); (ii) presumably low in phytate (Gibson *et al.*, 2010); and (iii) depending on the variety, could be a dietary source of β -carotene (Hagenimana *et al.*, 2001). Low (2013) and Greiner (2013) have reported that the orange-fleshed sweetpotato (OFSP) could significantly contribute to the reduction of VAD based on research findings from some African countries.

Data based on compositional analyses, viscosity and sensory attributes between household- and industrial-level ComFa formulations and Weanimix, a maize-soybean-groundnut blend, are evaluated in this chapter. Weanimix, was formulated through collaboration between United Nations Children's Fund (UNICEF) and the Nutrition Unit of the Ministry of Health, Ghana, to address protein-energy malnutrition among Ghanaian infants and young children (Agle, 1997; Lartey *et al.*, 1999). It contains 75–80% maize, 10–15% soybean/cowpea and 10% groundnut.

58.2 Food Formulation

With the aid of a nutrition calculator computer program, which was developed by Global Alliance for Improved Nutrition (GAIN), household- and industrial-level ComFa products were formulated (Table 58.1). As previously discussed by Amagloh *et al.* (2012c), the anchovy fish powder was included in the household-level ComFa formulation to improve the protein quantity and quality; skimmed milk powder was included for the industrial-level formulations as it is a common ingredient in industrial-manufactured infant cereals.

The proposed method for the household-level formulation was oven-toasting; thus, the product was referred to as oven-toasted ComFa. Extrusion-cooked ComFa and roller-dried ComFa were used to denote products processed using an extruder and roller-drier, respectively, as industrial-manufactured formulations. A detailed description of the processing of the ComFa formulations is available elsewhere (Amagloh *et al.*, 2012b).

58.3 Nutrient Composition of the Complementary Foods

All the formulations satisfied the energy (400 kcal/100 g) and fat (10–25 g/100 g) stipulated values for complementary food in the Codex Standard (Codex Alimentarius Commission, 1991). For protein, the extrusion-cooked ComFa and roller-dried ComFa were both 17% short of the protein specification of 15 g/100 g (Codex Alimentarius Commission,

1991) for complementary foods. It was suggested for the ComFa industrial-level formulations, the amount of skimmed milk used could be adjusted to satisfy the protein requirement (Amagloh *et al.*, 2012b).

However, data from Table 58.2 show that all the formulations met the estimated daily protein and fat intakes for 6–8-month-old breastfeeding infants from complementary food (Dewey and Adu-Afarwuah, 2008). None the less, for the energy requirements the ComFa formulations were lower by approximately 23% compared with the reference value of 200 kcal/day (Table 58.2). Weanimix was about 19% lower than the estimated requirement of energy per day. As it has been previously suggested, a serving size of 43 g (dry weight) of the ComFa formulations, instead of 33 g, would meet the suggested energy requirement (Amagloh *et al.*, 2012b).

Due to the lower starch:simple sugars ratio and the starch content of the sweetpotato-based formulations compared with that of Weanimix (Table 58.3), the ComFa formulations

Table 58.1. Ingredients and estimated levels of macronutrients of proposed sweetpotato-based complementary food (denoted as ComFa). (Adapted from Amagloh *et al.*, 2012c.)

Ingredient	Household-level product (g/100 g)	Industrial-level product (g/100 g) ^a
Cream-fleshed sweetpotato flour	66	72
Full-fat soybean flour	10	15
Soybean oil	6	6
Iodized salt	0.5	0.5
Sugar	0.5	0.5
Skimmed milk powder	–	6
Fish powder (anchovies)	17	–

^aFormulation for the industrial-level ComFa products: extrusion-cooked ComFa and roller-dried ComFa.

Table 58.2. Estimated daily nutrient intake from sweetpotato- and maize-based complementary foods against recommended daily requirements for 6–8-month-old breastfeeding infants in developing countries.^a (Adapted from Amagloh *et al.*, 2012b; Copyright 2012 © The United Nations University.)

Nutrient composition	ComFa			Weanimix	Reference value
	Extrusion-cooked	Roller-dried	Oven-toasted		
Energy (kcal/day)	153.20 ± 0.0c	152.93 ± 0.1c	154.98 ± 0.0b	162.14 ± 0.1a	200
Protein (g/day)	4.09 ± 0.03c	4.12 ± 0.03c	6.64 ± 0.05b	7.33 ± 0.04a	2
Fat (g/day)	3.32 ± 0.07c	3.43 ± 0.06b,c	3.52 ± 0.02b	3.71 ± 0.05a	0

^aValues shown are means of triplicate estimation ± standard error of the mean for ComFa formulations and Weanimix, based on estimated average daily intake of 33 g (dry weight) of complementary food from findings by Lartey *et al.* (1999); means in a row with the same letters are not significantly different ($P > 0.05$). Reference value: Dewey and Adu-Afarwuah (2008) for infants 6–8 months old with an average daily breastmilk intake of 600–650 ml/day.

Table 58.3. Carbohydrate composition^a (g/100 g dry matter basis) of sweetpotato- and maize-based complementary foods. (Adapted from Amagloh *et al.*, 2013b.)

Complementary food	Maltose	Sucrose	Free glucose	Free fructose	Starch ^b	Total dietary fibre	Total available carbohydrate
Extrusion-cooked ComFa	27.50 ± 2.54a	10.20 ± 0.31a	1.24 ± 0.04b	3.07 ± 0.37a	11.32 ± 1.87b	10.25 ± 2.29a	56.07 ± 1.97a
Roller-dried ComFa	30.85 ± 3.84a	10.53 ± 1.06a	1.34 ± 0.03a	2.94 ± 1.04a	10.53 ± 3.70b	10.57 ± 1.21a	58.92 ± 0.83a
Oven-toasted ComFa	25.43 ± 1.17a	10.08 ± 0.43a	1.40 ± 0.05a	2.61 ± 0.46a	13.75 ± 0.72b	8.16 ± 0.77a,b	53.28 ± 0.94a,b
Weanimix	1.06 ± 0.18b	2.01 ± 0.12b	0.07 ± 0.02c	0.39 ± 0.13b	46.72 ± 0.64a	6.08 ± 0.44b	50.25 ± 0.75b

^aValues shown are means ± standard deviation of triplicate estimates; values with the same letter in a column are not significantly different ($P > 0.05$).

^bStarch = total available carbohydrate minus the sum of maltose, sucrose, free glucose and free fructose; the starch content for extrusion-cooked ComFa and roller-dried ComFa was corrected for approximately 3 g/100 g of lactose from skimmed milk powder (FoodWorks, 2009) used as an ingredient.

formed a porridge with lower viscosity than Weanimix when cooked (Fig. 58.1). The naturally low viscosity of the ComFa products indicates that they would require less water during porridge preparation than the Weanimix.

Thus, there will be less 'energy and nutrient thinning' for the ComFa formulation. Also, it is likely that more of the composite flour of the sweetpotato-based formulation will be utilized during porridge preparation, and this may lead to increase in total solids per serving size as suggested above, contrary to dilution of porridge to reduce the viscosity in the case of Weanimix. Although the high viscosity of cereal porridge could be reduced by either malting or addition of amylase-rich flour (Moshia and Svanberg, 1990; Afoakwa *et al.*, 2010), this treatment is not required for the sweetpotato-based products.

It has been suggested that infants efficiently digest starch when it is present in food in small quantities (Weaver, 2000; Lentze, 2008). As a result of the lower starch:simple

sugars ratio and starch content, the ComFa product would be easier to digest by infants compared with Weanimix. The ease of digestibility could make nutrients more bioavailable. Human studies are required to investigate the true digestibility of sweetpotato- and cereal-based complementary foods.

Twenty female caregivers from SSA who had experience of feeding infants were recruited to carry out a consumer preference study of roller-dried ComFa, oven-toasted ComFa and Weanimix (Amagloh *et al.*, 2013b). Results (Fig. 58.2) indicate higher preference for the ComFa formulations than Weanimix. Additionally, the data show that caregivers were more willing to give the sweetpotato-based complementary foods than Weanimix. The levels of simple sugars in the ComFa compared with those in Weanimix (see Table 58.3) could partly explain the caregivers' greater liking for ComFa in the consumer preference test.

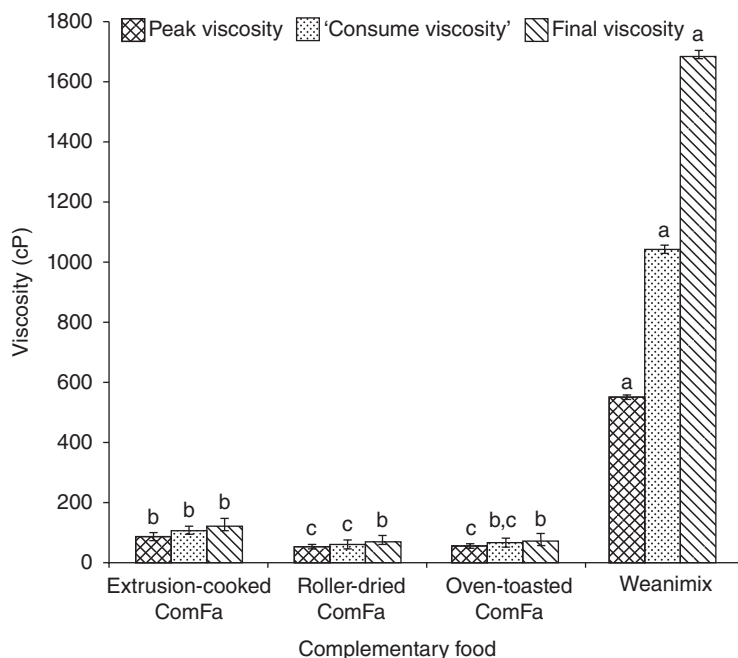


Fig. 58.1. Viscosity during cooking (peak viscosity), at serving ('consume viscosity') and during storage (final viscosity) of porridge from the complementary foods. Values shown are means of triplicate determinations \pm standard deviation; bars with a different letter for each variable for the complementary foods were significantly different ($P < 0.0001$). (Adapted from Amagloh *et al.*, 2013b.)

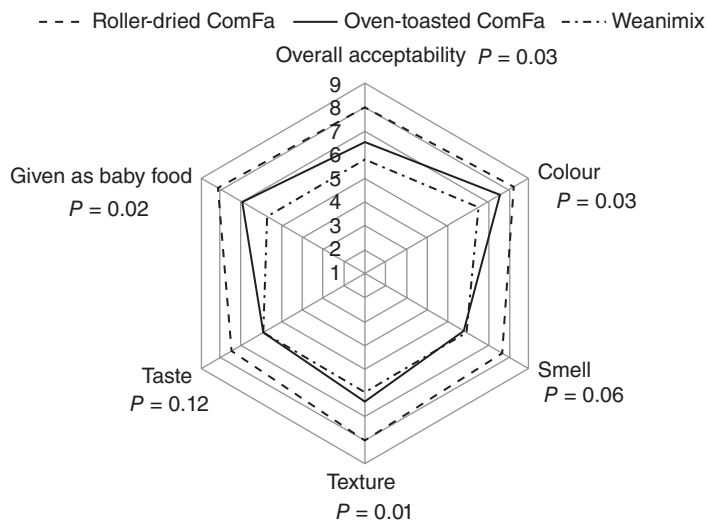


Fig. 58.2. Diagrammatic presentation of results of consumer preference study showing ratings given by 20 female caregivers for sensory attributes of formulations of infant complementary food (roller-dried ComFa, oven-toasted ComFa and Weanimix). A nine-point hedonic scale was used (where for sensory attributes: 1 = least acceptable/extremely dislike, 5 = neutral and 9 = highly acceptable/like very much; and for willingness to give product to babies: 1 = not likely, 5 = neutral, 9 = very likely). A sensory attribute with $P < 0.05$ indicates a significant difference among the complementary foods. (Adapted from Amagloh *et al.*, 2013b.)

58.4 Micronutrient and Antinutrient Levels

Only the ComFa formulations (Table 58.4) contained measurable amounts of vitamin A (β -carotene). Processing infant foods with OFSP could make the products an excellent dietary source of vitamin A (Low, 2013). Of nutritional significance is that most of the β -carotene in the oven-toasted ComFa was retained for up to 8 weeks when stored in containers with a good moisture barrier under simulated conditions of an average temperature of 32°C and relative humidity of 85% (Amagloh *et al.*, 2013a).

Data from Table 58.4 show that the ComFa formulations may inhibit calcium, iron and zinc absorption to a lesser extent than Weanimix using the phytate:calcium, iron and zinc molar ratios (Amagloh *et al.*, 2012a), indices that has been used by other researchers (Abebe *et al.*, 2007; Chan *et al.*, 2007; Gibbs *et al.*, 2011), to estimate the relative availability of these essential

micronutrients. Also, the β -carotene, which was present only in the ComFa products, has been reported to reduce the inhibitory effect of phytate and polyphenols on iron absorption (Garcia-Casal *et al.*, 2000; Layrisse *et al.*, 2000; Garcia-Casal, 2006). However, the high levels of polyphenols in the sweetpotato-based complementary foods (Table 58.4) may offset the benefit of the low levels of phytate on iron absorption (Ceramondi *et al.*, 2013). Petry *et al.* (2010) have shown that total polyphenols extracted from the hull of common bean (> 20 mg gallic acid equivalents per meal) reduced iron absorption, while Abizari *et al.* (2012) found that in cowpea-based flours, high concentrations of polyphenols do not limit iron absorption as there is a high phytate: iron ratio. Therefore, the source of polyphenols, and not polyphenols per se, could predict iron bioavailability. To our knowledge the effects of polyphenols extracted from sweetpotato on iron absorption have not been reported.

Table 58.4. Levels of micronutrients and antinutrients in sweetpotato- and maize-based complementary foods.^a (Adapted from Amagloh *et al.*, 2012a; Copyright 2012 © Informa UK, Ltd.)

Complementary food	β -carotene ($\mu\text{mol/kg}$) ^b	Calcium (mg/kg)	Iron (mg/kg)	Zinc (mg/kg)	Phytate (mg/kg)	Total polyphenols (mg gallic acid equivalents/kg)
Oven-toasted ComFa	28.73 \pm 0.79a	6008.40 \pm 633.34a	69.74 \pm 0.37a	21.17 \pm 0.75b	2263.70 \pm 320.01b	2195.09 \pm 162.35a
Roller-dried ComFa	24.84 \pm 0.87a	2017.70 \pm 18.28b	27.88 \pm 1.26b	15.79 \pm 0.25c	1949.70 \pm 208.40b	2039.85 \pm 85.61a
Weanimix	ND ^c	3707.80 \pm 251.17b	81.22 \pm 4.49a	30.69 \pm 0.21a	8032.70 \pm 356.81a	1923.95 \pm 152.25a

^aValues shown are means of triplicate estimations \pm standard error of the mean reported on a dry matter basis, except for β -carotene which is the mean of duplicate estimations. Mean values within a column with the same letters are not significantly different ($P > 0.05$).

^bNot detected at the minimum detection limit of 0.09 $\mu\text{mol/kg}$ for β -carotene; 1 μmol β -carotene = 537 μg β -carotene.

^cND, not detected.

58.5 Some Nutritional Concerns of the Sweetpotato-based Products

The sweetpotato-based formulations had total dietary fibre (Table 58.3) that was about twice the maximum specification of 5 g/100 g by the Codex Standard (Codex Alimentarius Commission, 1991; FAO and WHO, 2011). This may be a nutritional concern for using the sweetpotato-based product for complementary feeding based on the recommendation in the Codex Standard if the fibre was all insoluble. Preliminary data from subsequent work yet to be published indicate that about 20% of the fibre is soluble so it has the potential to act as a substrate for the growth of beneficial colonic microflora such as lactobacilli and bifidobacteria (Anderson *et al.*, 1994, 2009).

Other limitations of the ComFa formulations are: (i) the cream-fleshed sweetpotato used in our studies has lower β -carotene content compared with OFSP (Burri, 2011); (ii) the drudgery and cost involved in the flour preparation; and (iii) the total degradation of ascorbic acid as a result of the flour processing.

Therefore, there is the need to investigate other product development methods that will eliminate the processing of flour.

58.6 Recommendation for an Alternative Approach for Preparation of Sweetpotato-based Complementary Food

This alternative approach does not involve flour preparation from the sweetpotato roots. The roots, after washing, could be chipped and all the other ingredients listed in Table 58.1 could be added, and the mixture boiled to cook. The chips could be mashed into the broth when soft, and could be served to infants. The proposed formulation is more attractive as: (i) there will be a cost saving (the drying and milling cost is eliminated); (ii) preparation is less time consuming (no need to dry the chipped roots); and (iii) it could possibly result in a

formulation with higher levels of essential micronutrients such as ascorbic acid and β -carotene.

58.7 Conclusion

The sweetpotato-based formulations contain less phytate than Weanimix, and thus there is likely to be less inhibition of iron and zinc absorption; and they also contain carotenoids, making such formulations a sustainable source of dietary vitamin A to complement vitamin A supplementation initiatives in low-income countries in SSA. More importantly, the sweetpotato is extensively grown as a secondary food crop in most countries in SSA (Low, 2013).

On the basis of the compositional analyses carried out in this study, the ComFa formulations have the potential to be a valuable complementary food introduced after the period of exclusive breastfeeding, particularly for infants in low-income countries, where prevalence of micronutrient deficiencies, particularly vitamin A, remains high.

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