NUTRITIONAL AND RHEOLOGICAL PROPERTIES OF SWEET POTATO BASED INFANT FOOD AND ITS PRESERVATION USING ANTIOXIDANTS

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ABSTRACT

Sweet potato based infant food was developed according to micro-diet database program, 2000, Down lee Systems Limited. Two sweet potato based recipes were formulated and their nutritional properties and digestibility measured using standard analytical methods. The viscosity or consistency of a baby food was critical and was determined by measuring the rheology of the product. The oscillation technique was used to determine the elastic energy stored (G') and the energy dissipated due to viscosity (G''). The effects of antioxidants on lipid oxidation of the developed products on storage were also investigated. The recipes were compared with two commercial infant food products; Heinz baby food and cerelac®. The mean ± SD for moisture, total carbohydrate, protein, crude fat, and ash per 100 g dry weight were 8 ± 0.4, 66 ± 0.2, 20.4 ± 0.1, 2.0 ± 0.1, 3.2 ± 0.8 g, respectively for recipe A, and 8.4 ± 0.6, 58 ± 1.4, 28 ± 0.4, and 3.4 ± 0.5, 2.0 ± 0.0 g, respectively for recipe B. The *in vitro* digestibility for recipes A, B and commercial food (cerelac®) were 69.5 ± 0.2, 67.4 ± 0.1 and 64.9 ± 1.9% respectively. The G' values of the formulated products A, B, Heinz baby food and cerelac® on heating and cooling were 564, 492, 346, 21 Pa. The rheological characteristics of the two formulations were comparable to a commercial Heinz baby food obtained from local super market. The G' and G'' values of commercial infant food product cerelac® were very low compared with the formulated product. The results indicated that nutritional characteristics of sweet potato based products were comparable to the commercial baby food, cerelac® used in Uganda. The formulated food was within the accepted consistency (< 500 Pa) after heating and cooling and hence may be a potential complementary food. The lipid oxidation for recipe A with fish was significantly reduced by using antioxidants (500 mg Vitamin C, 500 mg Vitamin E and 100 mg of Citric acid) whereas recipe B did not need any antioxidants.

Key words: processing, rheology, sweet potato, antioxidants

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INTRODUCTION

When a baby reaches four to six months of age, breast milk alone is no longer sufficient to meet its nutritional requirements. Calories and other nutrients from weaning foods are needed to supplement breast-milk until the child is ready to eat the family diet. Traditional weaning foods in Uganda are known to be of low nutritive value and are characterized by low protein, low energy density, low vitamin A and a high antinutrient activity (phytic acid and fibre) [1,2]. Cereals form the primary basis for most traditional weaning foods in Uganda yet cereals have low protein content and are bulky. While it may be possible to achieve an adequate protein-energy intake for older children and adults by increasing the daily intake of cereal-based foods, for infants and small children the volume of the traditional diets required to meet energy needs are too large for the child to ingest.

To reduce the incidence of malnutrition, tubers and roots offer a potential alternative to cereals as weaning foods. Orange-fleshed sweet potato was selected in this study as a potential raw material because of its high β-carotene content, which makes it very important in alleviating vitamin A defficiency among children below 6 years. It is also a very good source of minerals such as potassium, magnesium, zinc and folate [3]. In addition, sweet potato is adaptable to diverse environments, has high yields, performs well in marginal soils, is available all year round and is cheap to grow. Globally sweet potato is an important staple food or base material for variety of food and industrial applications. The sweet potato based food product may also have advantages as infant food over other cereal based baby foods, especially wheat and wheat related cereals, due to its hypoallergenic effect [4]. In addition, a sweet potato based infant food would not require the use of external sweeteners which, in part reduces its production costs. Sweet potato incorporated with legumes or fish and oil can produce a nutritious product, provided it is protected from spoilage.

Foods especially fatty fish and oils often go rancid as a result of lipid oxidation. Lipid oxidation results in products such as aldehydes, hydroxides, hydrocarbons, which contribute to off flavours, bad taste, change in texture and the nutritive value of the food, which may be toxic [5,6,7,8]. To stabilise the lipid containing food product, antioxidants are often used to reduce fat oxidation [9]. Antioxidants work by scavenging the active forms of oxygen involved in the initiation step of oxidation, or can break the oxidative chain reaction by reacting with the fatty acid peroxy radicals to form stable antioxidant radicals, which are insufficiently reactive to continue the chain reaction.

The antioxidants can be synthetic or natural. Synthetic antioxidants include propyl gallate, butylated hydroxyl anisole (BHA), butylated hydroxytoluene (BHT) and tertiary butylhydroxyquinone (BHTQ). Consumers are concerned about the health risks related to the consumption of some of these synthetic antioxidants, as some laboratory studies with animals have hinted at carcinogenicity of BHA and BHT [10]. Although the issue is far from being resolved, there is growing pressure for

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their withdrawal from use. Hence research is now focusing on the use of natural antioxidants such as vitamin E, Vitamin C and other plant phenolic substances [11] The aims of this study were to formulate a dried infant food product using sweet potato; to investigate the nutritional and rheological properties of the product and to study the effects of antioxidants (Vitamin E and C) on lipid oxidation in the product during storage

MATERIALS AND METHODS

Materials
Orange fleshed sweet potato roots (SPK 004) were obtained from Namulonge Agriculture Research Institute, Uganda. Fish (Tilapia skinned fillets), sun flower oil, skimmed milk, were bought from the Tesco supermarket, Guildford, UK. Cerelac® and Heinz baby food; a puree manufactured by Heinz, Canada were purchased from Tesco departmental store at Guildford, UK

METHOD

Preparation of sweet potato
Medium roots of SPK 004 (weight 200g, length 20cm and diameter 6cm) were selected, sliced and freeze-dried

Formulation of weaning food
The formulation of weaning food was carried out using the Micro diet program version 1 2000, Down lee Systems Limited. The composition of the food in the Micro diet programme is based on the McCance and Widdowsons (4th and 5th edtn, 2000). Two recipes were prepared; Recipe A contained dried sweet potato 128g, Tilapia 40g, soya 85g, sunflower oil 15g and water 732g; Recipe B had dried sweet potato 80g, soya flour 41g, skimmed milk 41g, sunflower oil 28g and water 810g. The ingredients were blended into a soft paste and prior to cooking antioxidants were added particularly to the recipes that contained fish since it was reported that about 50% of the antioxidants are destroyed on cooking [12]. Besides, fish deteriorates so fast that it is necessary to add antioxidant before cooking to avoid oxidation of fish oil. Antioxidants (Vitamin C, powder form and Vitamin E in oil form were added as indicated in Tables 1 and 2. The vitamins C and E were obtained from Sigma-Aldrich Company Ltd, Poole, England. After cooking, the sample were frozen in -80ºC freezer, freeze-dried and ground into a fine powder using pestle and mortar. The dried food was then stored in sealed polyethylene bags at room temperature (22ºC) to simulate the conditions of storage in developing countries. Some of the samples without antioxidants were used for analysis of proximate composition and rheological characteristics.

Proximate composition
The proximate composition of sweet potato was determined according to the standard analytical methods [13]. All determinations were carried out in triplicates.

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Moisture content was determined by drying a sample in an oven at 100ºC for 12hours; the weight loss incurred was calculated as;

$$\% \text{ moisture} = \frac{\text{Weight loss on drying} \times 100}{\text{Weight of sample}}$$

Ash was determined by burning weighed dried samples on a Bunsen flame to remove moisture. The samples were heated in a muffle furnace at 550ºC overnight. The samples were transferred into a crucible, cooled and weighed immediately. Ash was calculated as follows

Weight of Ash g = (weight of crucible + ash) – (weight of crucible).

Crude protein was determined by the Kjeldahl's method, which measures total nitrogen. The crude protein content was obtained by multiplying the total nitrogen content by a factor of 6.25.

Lipid content was determined using Soxhlet extraction method. The free lipid content and free fatty acids were determined by extracting the dried material (food samples) with a light petroleum fraction in a continuous extraction apparatus. The solvent was distilled off and the extract was dried and weighed.

In vitro digestibility of starch
In vitro digestibility of starch in the flour was measured according to Singh's method with some   modification [14]. Dried samples (50 mg) were placed in test tubes and 1.0 ml of phosphate buffer (0.1 M, pH 6.9) added. The suspension was boiled for 10 minutes to gelatinise the starch. The solution was transferred to a water bath at 37 ºC and 0.5 ml of pancreatic amylase (20 mg of amylase dissolved in 50 ml phosphate buffer pH 6.9) was added. This was incubated for 2 h. The hydrolysate was diluted 10 times and maltose formed was measured spectrophotometrically. The reducing sugar (maltose) was determined using a dinotrosalicyclic acid reagent [15]
Starch digestibility (%) was expressed as;

$$\frac{\text{Mg maltose liberated} \times 100}{\text{Mg starch in flour sample}}$$

Rheological measurements
Formulated food samples and commercial were tested on rheometrics controlled stress rheometer 200 using 40 mm parallel plate geometry with a gap of 1.0. Silicone oil was applied to prevent evaporation during heating. The temperature of the peltier plate was programmed to ramp at a rate of 1ºC min^{-1} from 20 to 90ºC and cooled to 20ºC at the same rate. A frequency of 1 rad s^{-1} was used and the applied stress was 1.0 Pa. The G' (Elastic energy stored) and G'' (energy dissipated) values were noted at 20ºC before heating, at 90ºC and 20ºC after cooling.

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Measurement of lipid oxidation

Lipid extraction from freeze-dried infant food
Lipids were extracted from the formulated infant food by Saeed and Howell's method [16].

Peroxide value determination
Peroxide value was determined by iodometric titration method as described in [13].

Hexanal determination
The hexanal method was kindly supplied by Masterfoods plc (Masterfoods, central nutrition and microbiological laboratories, UK).

Standard preparation
Stock hexanal (0.1g) was weighed into 100 ml volumetric flask with cyclohaxane.
Stock isobutyl acetate (0.1 g) was weighed into 100 ml volumetric flask with cyclohexane.
Internal standard: 2 ml of stock isobutyl acetate was pipetted into 100 ml volumetric flask and was made to 100 ml mark with cyclohexane.
Working standard: 2ml of both stock solutions hexanal and isobutyl acetate were pipetted into a 100 ml volumetric flask and made to volume by adding cyclohexane.

Preparation of sample
The sample (10 g) in triplicates was weighed 500 ml round bottomed flask and saturated sodium chloride solution (150 ml) was added followed by spatula granules. Internal standard (2 ml) was pipetted into this mixture and the flask was placed on a heating mantle. A Clevenger trap was fitted and switched on. The mixture was refluxed on the heating mantle for 15 min and left to cool for 15 min. Using a pipette the cyclohexane layer was transferred from Clevenger to a vail and was injected onto the Gas chromatography. The chromatographic conditions were the run time was 17.60, injection volume, 4μl and the retention times for isobutyl acetate was approximately 6.2 and for hexanal was 7 min.

The concentration of hexanal was calculated as follows:
$$\frac{\text{Sample ratio}}{\text{Average Standard Ratio}} \times \text{Hexanal standard concentration} \times \frac{\text{Internal standard amount}}{\text{weight of sample}}$$

$$\text{Sample ratio} = \frac{\text{Peak area of hexanal}}{\text{Peak area of IBA}}$$

Average standard ratio = average ratio of calibration working standard run.
Internal standard amount = 2 ml.

Statistical analysis
Statistical analysis was performed using Insat software. The student's t Test was employed to detect any possible differences between the untreated (samples with out antioxidants) and treated samples (samples with antioxidants).

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RESULTS

Proximate composition and *in vitro* digestibility

The results for proximate composition and *in vitro* digestibility are indicated in Table 3. The proximate composition of the formulated products compared well with the commercial baby food cerelac. The *in vitro* digestilibility of the formulated products and commercial foods ranged from 65 to 69%.

Rheology

The viscoelastic properties of the formulated products are presented in Table 4. The G' values for both recipes A and B were low before heating and increased slightly on heating. After heating and cooling G' values increased further but these values were not very high and the samples were still soft enough for infant feeding. The rheological characteristics of the sweet potato based infant foods formulated were comparable to the commercial Heinz baby food obtained from local supermarket and its G' value on cooling was < 500 Pa (Table 4)

Effects of antioxidants on freeze-dried weaning foods during storage

The results for peroxide value (PV) and hexanal content for baby food A are shown in Figures 1 and 2 respectively. The peroxide value for the untreated baby food with fish (Recipe A) was 7.07 mEq/kg in week one and increased to 47.9 mEq/kg in week four and peaked to 88 mEq/kg in week 16. The increase was throughout the storage period from week 1 to week 16. The increase was higher compared to samples with antioxidants. There was a significant difference (p<0.001) in peroxide values between the food with antioxidants, particularly at concentrations (350; 350; 100 mg/kg), (500; 500; 100 mg/kg) (Vit E + C + citric acid) and food without any antioxidants. There was a general increase of hexanal values in all the samples on storage but the ones stored with antioxidants increased slowly (Figures 2). The Recipe A samples without antioxidants had 1.21 μg/g hexanal levels at the beginning of storage and increased to 5.71 μg/g in week four. It further peaked at 8.38 μg/g in week 12 and dropped to 5.68 μg/g in week 16. Those samples with antioxidants particularly with low antioxidant levels (200 mg Vitamin E and C) increased from 0.76 to 3.47μg/g while hexanal content in the samples with highest level of antioxidants increased from 0.31 to 3.47 μg/g.

Recipe B samples responded differently to antioxidants from recipe A samples. In all the samples there was an increase of peroxides and hexanal on storage. In all treatments the peroxide values increased from week one to week 12 and reduced in week 16. The trend was the same with hexanal content for recipe B. The control samples without antioxidants were less oxidized than samples with antioxidants (Figure 3 and 4). There was a steep increase in peroxide and hexanal values on adding a high concentration of antioxidants (Figures 3 and 4), a response quite opposite to that of baby food with fish.

DISCUSSION

The proximate composition of recipe A and B compared quite well with that of commercial baby food, cerelac used in Uganda. The energy contribution by the macronutrients such as carbohydrate, fat and protein were achieved as required by the WHO/FAO guidelines [17].

From the age of 5 or 6 months infants grow and develop very fast and breast milk is not enough to meet their nutritional demands and they therefore require an adequate diet that can meet their nutrient needs. The results indicate that the baby foods produced are nutritionally adequate and suitable for infant weaning. *In vitro* digestibility of starch in the foods indicated that the carbohydrates may be well utilised. It is important to have an easily or readily digested carbohydrate to avoid using proteins as source of energy. Inadequate energy obtained from carbohydrate would force the body to utilize protein as source of energy. The protein is mainly required for growth or provides precursors for tissue repair.

Since an infant needs a gradual transition from fluid to solid foods over the weaning period, it is necessary that solid foods be introduced gradually starting with soft ones. In all cases nutritional quality should not be compromised. Thus, the viscosity or consistency of a baby food is critical and was determined by measuring the rheology of the product. The oscillation technique is used to determine the G' which is a measure of the elastic energy stored and G'' which is a measure of the energy dissipated due to viscous behaviour. The product formulated in this study had low viscoelasticity values on both heating and cooling. Addition of other ingredients such as fish, soya, milk and oil led to lowering of G' and G'' values probably due to phase separation or due to the fat in the formulae, which may have reduced the viscoelasticity by formation of fat layer around the starch granules thus reducing water absorption of the starch during cooking [2]. In addition the lipid also minimises protein interactions thus lowering G' values [2].

The quality of foods containing oil/fat deteriorates on storage due to oxidative processes induced by atmospheric oxygen. In this study oxidation was monitored by measuring the primary (peroxides) and secondary products (aldehydes such as hexanal) products using peroxide values and gas chromatography techniques respectively. Two recipes A and B were studied to monitor the changes of lipids on storage.

The increase in peroxide values and then a drop over time (Figure 3) observed in this study had also been reported [8, 9]. A decrease of peroxide value confirms that peroxides were unstable components and were broken-down to produce aldehydes such as malondialdehyde and hexanals [18]. When storage is further extended, it could be postulated that the rate of peroxide break-down exceeds the hydro peroxide formation rate. This could also account for the general increase of hexanal levels. The decrease in hexanal levels (Figure 4) with time is because the carbonyls are unstable and react easily with other compounds [18]. The antioxidants with high concentration were more effective in reducing the lipid oxidation (Figure 2) in the

product containing fish (recipe A), suggesting that the antioxidant activities are concentration dependent. The optimum levels of antioxidants required to stabilise the lipids in the baby food (Recipe A) is 350-500 mg/kg Vit E, C and 100 mg citric acid, which is comparable with previous findings [19, 20]. These researchers reported that the optimum concentration of α-tocopherols required for stabilising the soya oil and palm oil was 200 and 500 mg/kg respectively. The beneficial effect of using vitamin E, C and Citric acid (250 mg/kg, 250 mg/kg and 100 mg/kg respectively) for stabilising fish fillets and dried fish products was reported [12].
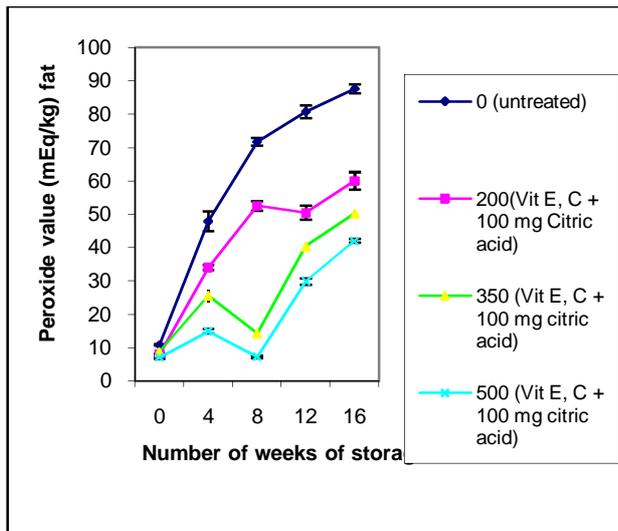

Figure 1:   **Peroxide values obtained from freeze-dried baby food with fish (recipe A) stored at 22ºC for 16 weeks.**
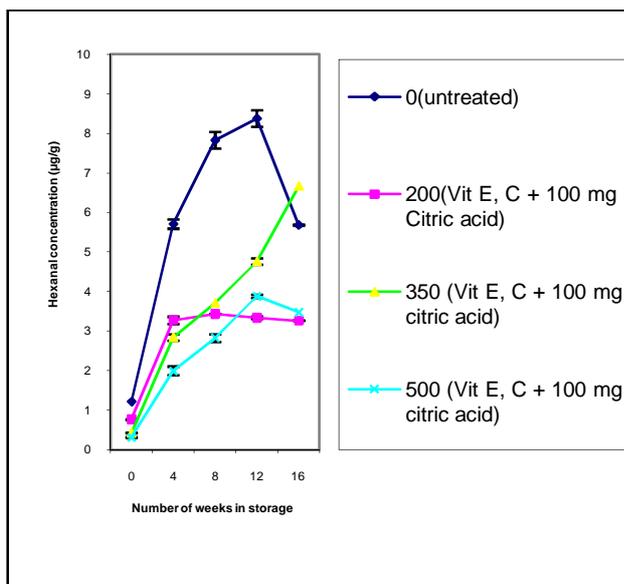
Figure 2:   **Hexanal values obtained from freeze- dried baby food with fish (recipe A) stored at 22ºC for 16 weeks.**

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Lipid oxidation in the recipe B (baby food without fish) was not inhibited by the addition of antioxidants as observed in the product containing fish. In all the samples there was an increase of peroxides and hexanal on storage. Surprisingly the control samples without antioxidants were less oxidized than samples with antioxidants. It is possible that the product contained its own natural antioxidants that protected it leading to lower levels of peroxides as indicated in Figure 3 below. The high concentration of antioxidants may have exacerbated the problem of lipid oxidation. There was a steep increase in peroxide and hexanal values on adding a high concentration of antioxidants (Figure 3 and 4) a response quite opposite to that of baby food with fish. Fish lipids generated enough free radicals, which were counteracted by the antioxidants. However the initial free radical production in the recipe without antioxidant was low to begin with. It seems antioxidants in the recipe B without fish acted as pro-oxidants. It has been reported that vitamin C can act as an antioxidant or pro-oxidant depending on the concentration, presence of metal ions and the tocopherol content [21]. It is also reported that vitamin C at low concentrations (20-100 mg/l) acted as pro-oxidant while at high concentration higher than 500 mg/l acted as antioxidant [22]. The level of vitamin C added to recipe B ranged between 50 and 250 mg/kg. It is also noted that α- tocopherol is capable of becoming a pro-oxidant in fats [23]. Therefore antioxidants must be added with sufficient recognition of the pro-oxidant and antioxidants behaviour in the matrix to be protected.
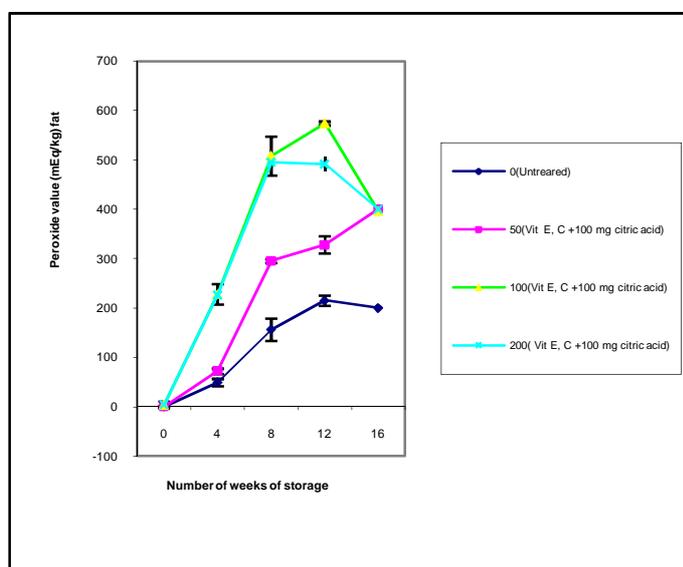
Figure 3: **Peroxide values obtained from freeze-dried baby food without fish (recipe B) Stored at 22ºC for 16 weeks**

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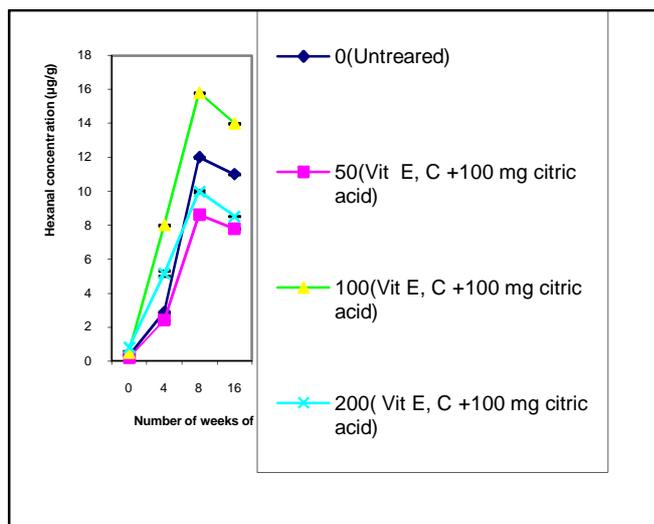Email: oniango@connect.co.ke   OR   info@ajfand.net   www.ropkenya.org

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Figure 4: **Hexanal values obtained from freeze-dried baby food without fish (Recipe B) stored at 22ºC for 16 weeks**

CONCLUSION

Sweet potato based infant food developed in this study may be a potential weaning food because of its nutritional values and viscoelastic properties, which compared well with commercial baby foods. The shelf life of the formulated food containing fish may be increased by use of antioxidants vitamin E, C and citric acid. However antioxidants were not needed in the products without fish. It is important that the levels of antioxidants are chosen carefully to avoid pro-oxidation. In general there is a need to investigate the appropriate combination of antioxidants that can inhibit oxidation of fat in different food samples.

ACKNOWLEDGEMENT

Table 1: Antioxidants added to recipe A

Sample	Vit. C (mg/kg)	Vit. E (mg/kg)	Citric acid (mg/kg)
I	0	0	0
II	200	200	100
III	350	350	100
IV	500	500	100

Table 2: Antioxidants added to recipe B

Sample	Vit C (mg/kg)	Vit E (mg/kg)	Citric acid (mg/kg)
I	0	0	0
II	50	50	100
III	100	100	100
IV	250	250	100

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Table 3: Proximate composition of sweet potato based food

Nutrient	g/100g dry weight basis Recipe A	g/100g dry weight basis Recipe B	Cerelac (g/100g)
Moisture	8.0 ± 0.4	8.4 ± 0.6	2.5
Carbohydrate	66.0 ± 0.2	58 ± 1.4	69.5
Protein	20.4 ± 0.1	28.0 ± 0.4	15.0
Fat	2.0 ± 0.1	3.4 ± 0.5	9.0
Ash	3.2 ± 0.8	2.0 ± 0.0	2.6
Invitro digestibility	69.5 ± 0.2	67.4 ± 0.1	64.9 ± 1.9

Table 4: Elastic modulus (G') values and G'' (loss modulus) for sweet potato-based food, Heinz baby food and Cerelac at 20°C (beginning of the heating cycle) 90 and 20 °C (end of the cooling cycle)

Visco-elasticity	Temperature °C	Recipe A	Recipe B	Heinz baby Food	Cerelac
G' (Pa)	20	113 ± 39.0	91 ± 8.0	434 ± 28.6	10.1 ± 1.1
G'' (Pa)	20	71.2 ± 21	205 ± 8.0	208 ± 7.5	7.7 ± 0.6
G' (Pa)	90	166 ± 3.2	242 ± 8.2	183 ± 23	3.8 ± 0.8
G'' (Pa)	90	136 ± 18.0	53 ± 2.4	77.3 ± 18	3.1 ± 0.4
G' (Pa)	20	564 ± 9.1	492 ± 9.4	346 ± 32.3	21.0 ± 0.9
G'' (Pa)	20	196 ± 33	118 ± 20	121 ± 56	25.4 ± 3.6

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