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Full Length Research

Nutritional and sensory qualities of extruded Ready-To-Eat baby foods from orange-fleshed sweet potato enriched with amaranth seeds, and soybean flour

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ABSTRACT: Adequate nutrition is critical during infancy and childhood because life phases are marked by significant physical, mental, and changes in behaviour, such as fast growth, weight gain, the development of cognitive and psychomotor abilities, and a change in dietary preferences. This study was carried out to investigate the effect of extrusion cooking and blend proportions on the nutritional qualities of extruded ready-to-eat baby foods. Different blends of orange-fleshed sweet potato, amaranth seeds, and soybean flour were used to formulate foods and analyzed for proximate, minerals, vitamin A content, anti-nutrient content, physical properties, and sensory qualities. Extrusion cooking was conducted at a temperature of 90ºC, screw speed of 400 rpm, and feed moisture content of 35%. The results reveal that extruded ready-to-eat baby foods had a high protein content of 15.72%, total minerals (5.39%), carbohydrate content (80.58%), crude fibre content (5.04%), fat content (6.05%), energy value (380.84 kcal/100g), energy-to-protein ratio (128.67 kcal/g of protein) and vitamin A content (1044.70 REA µg/100g). The micronutrients of extruded baby foods resulted in high iron content of 3.10 mg/100g, zinc content (0.64 mg/100g), manganese content (0.90 mg/100g), copper content (0.97 mg/100g), magnesium content (81.70 mg/100g), calcium content (61.22 mg/100g), potassium content (68.18 mg/100g) and sodium content (41.44 mg/100g). The produced ready-to-eat baby foods showed a reduction in anti-nutrients as well as acceptable levels of phytate content which ranged from 0.47-1.79 mg/100g, oxalate content (0.16 – 0.50 mg/100g) and saponin content (0.20 – 0.48 mg/100g). All produced foods were highly accepted through sensory evaluation. These important findings confirm that extrusion cooking is useful in the production of nutrient-dense baby foods. In addition, the most significant observation of this study is that the produced foods could be used for under-five years children who suffer from protein-energy malnutrition and micronutrient deficiencies. These findings will also contribute to food and nutrition security.

Keywords: Amaranth seeds, extrusion cooking, nutritional content, orange-fleshed sweet potato, ready-to-eat extrudates, sensory characteristics, soybean.

INTRODUCTION

Nutrition is the collection of physiological activities that include food intake, digestion, absorption, assimilation, and egestion of undigested food from the alimentary canal and also its impact on human growth and development (Gupta, 2020). Poverty, food insecurity, child malnutrition, and unaffordability of healthy foods continue to be a challenge, particularly in Africa and Asia in vulnerable groups including children (FAO *et al*., 2021). Malnutrition is caused by poverty, inadequate nutritional quality of traditional complementary food, inappropriate complementary feeding practices, high disease burden, limited access to nutritious foods, low level of mother's education, low access to safe water and basic drugs, sanitation, and hygiene and health services, and inadequate care practices and the increased cost of protein-based complementary foods (Eka *et al*., 2010, WFP, 2018). During the COVID-19 pandemic, interruptions in important nutrition measures and unfavourable impacts on food patterns hampered efforts to eradicate malnutrition in all of its manifestations (FAO *et al*., 2021). Poor weaning is one of the most common causes of child malnutrition, which raises the risk of baby morbidity and mortality (Jeelani *et al*., 2020).

According to the most current figures, several people are still suffering from poverty, hunger as well as malnutrition (Global Nutrition Report, 2021). Stunting and wasting are still very high globally. Sub-Saharan Africa accounted for 32.3% while Eastern Africa accounted for 32.6% of under-five years children stunted in 2020. The level of wasting of under-five years children in sub-Saharan Africa was 5.9% and 5.2% in Eastern Africa in 2020. Furthermore, severe food insecurity in sub-Saharan Africa was 24.8% while in Eastern Africa was 27.3% between 2019 – 2021. Thus, the undernourishment situation in the total population in sub-Saharan Africa was 22.0% whereas in Eastern Africa was 29.2% between 2019 – 2021 (FAO *et al*., 2022). Adequate nutrition is required for newborns and children to reach their maximum potential in terms of growth, health, and development. Nutritional deficiencies render the body vulnerable to sickness. A range of biological, environmental, and social variables influence the growth of a child. The growth of children is inhibited when they are malnourished throughout their first two years of life. Undernutrition during the first 1000 days of life is connected to a reduced survival rate and a higher frequency of acute and chronic disorders in adulthood (Rajesh *et al*., 2020). A recent study by FAO *et al*. (2022) revealed that most East African Community countries still have high rates of stunted and wasted children. The prevalence of stunted children under five years is high in Burundi (57.6 %) and the Democratic Republic of the Congo (40.8 %), followed by Rwanda (32.6 %), Tanzania (32.0%), South Sudan (30.6%), Uganda (27.9%), and Kenya (19.4%) while the largest prevalence of wasted children of under five years children is in the Democratic Republic of the Congo (6.4%), followed by Burundi (4.8%), Kenya (4.2%), Tanzania (3.5%), Uganda (3.5 %) and Rwanda (1.1 %).

On the other hand, anaemia is still high, rising, and prevalent among girls and women of reproductive age, with 570.8 million (29.9%) of girls and women of reproductive age (15–49 years) suffering from anaemia (Global Nutrition Report, 2021). The findings show striking geographical differences: anaemia impacted more than 30 % of women in Africa and Asia, compared to only 14.6 % of women in Northern America and Europe (FAO *et al*., 2021). Likewise, in low- and middle-income countries, approximately 60% of children under the age of five are anaemic (with greater rates among those aged 6–24 months), with no improvement over the last decade (Zlotkin and Dewey, 2021). Data on micronutrient deficiencies (vitamin A deficiency) in children suggests that the problem is still prevalent throughout Africa and South Asia. In the few countries where data exists, zinc deficiency affects nearly half of all children (Victora *et al*., 2021). The simplest and least expensive method to reduce the burden of many diseases and the predisposing factors with them is adopting a proper diet (Rajesh *et al*., 2020).

A potential solution to nutrition and food insecurity could be the blending of locally available food crops to produce affordable, sustainable, and healthy diets and the utilization of low-cost processing techniques. OFSP has been used to boost vitamin A content in infants' food but it has low protein, fat, and some mineral contents (Amagloh and Coad, 2014). Soybean incorporation could help to increase protein, fat, and minerals. However, the protein quality of both OFSP and soybean has low levels of some amino acids but is high in amaranth seeds (Mendoza and Bressani, 1987). Therefore, orange-fleshed sweet potato enriched with soybean and amaranth seeds can boost nutrients specifically micronutrients (vitamin A and minerals) and macronutrients such as protein, fat, and carbohydrate. The amaranth species are crops with a lot of potential for reducing hunger, malnutrition, and poverty and not only reducing illnesses that may associate with them but also achieving food and nutrition security. Amaranth is a high-yielding crop and can withstand a lot of stress conditions. Amaranth seeds have a high nutritional value and bioactive components, and a wide range of applications in both household and industrial applications (Aderibigbe *et al*., 2020).

On the other hand, antinutritional factors are substances or compounds of natural or synthetic origin that hinder nutrient uptake, digestion, and utilization in addition to having other detrimental consequences. Numerous antinutrients in the body can lead to symptoms like nausea, bloating, headaches, rashes, nutritional deficiencies, and other issues. Anti-nutrient can be advantageous for a human being when consumed appropriately. However, plants predominantly use antinutrients as a form of defence. Antinutrients are typically removed from products through thermal processing, including extrusion, autoclaving, hydro techniques, and enzymatic and harvest treatments, among others (Awulachew, 2022).

Extrusion cooking allows for quicker processing, relatively cheaper, no process effluents, high productivity, significant nutrient retention, less space for the plant required for processing equipment, little labour, and greater flexibility leading to more types of end-products (Alam *et al*., 2016). It provides several advantages, including improving protein digestibility and total dietary fibre while lowering lipid oxidation, microbial contamination, and anti-nutritional factors, all of which are important in the production of a range of extruded food products (Mathad *et al*., 2022). Therefore, this research was carried out to determine the effect of blend proportions and extrusion temperature on the nutritional and sensory qualities of extruded ready-to-eat (RTE) baby foods produced from orange-fleshed sweet potato, soybean, and amaranth seeds flour blends.

MATERIAL AND METHODS

Orange-fleshed sweet potato variety Kenspot 5, and soybean of variety DPSB 19 were bought from KALRO (Kenya Agricultural and Livestock Research Organization), Njoro, Kenya, and amaranth seeds of variety Katumani Amaranth (KAM) 001 was procured from KALRO, Katumani, Machakos, Kenya.

Production of flour from orange-fleshed sweet potato, amaranth seeds, and soybean

Orange-fleshed sweet potato flour was processed according to Honi *et al*. (2017), amaranth seeds flour was produced based on the method described by Shevkani *et al.* (2014) while soybean flour was manufactured according to Shokunbi *et al*. (2011).

Blend formulations and extrusion cooking process

The blends used in this work were identified from the trial run and the available literature. The flour (100 g), sugar (15%), salt (1.5%), baking fat (1.5%), and vanilla essence (1.0 ml) were gently combined to produce a dough. Distilled water (35 ml) was progressively added while mixing until a well-textured, relatively hard dough was achieved. The dough was kneaded on a clean flat surface. A twin screw Extruder (PSHJ-20, Jiangsu Xinda Science and Technology Co.Ltd, China) was used for processing extruded ready-to-eat baby foods. The extruder was set at different conditions where, die temperature, screw speed, and feed moisture content were 90°C, 400 rpm, and 35%, respectively. In addition, end barrel temperature (metering zone) varied from 70-90°C while entry (feeding zone), and centre (compression zone) barrel temperatures were kept constant at 70°C. The firm dough was fed on the hopper of an extruder and extrudates were collected at the end zone of the extruder (die section), dried at 55±5°C, cooled, and sealed in plastic polyethylene bags of 26.8 cm by 27.3 cm, and stored at room temperature (24±4°C) prior for physicochemical analysis.

Experimental design

A Completely Randomized Design (CRD) in a Factorial Experimental Design with two variables (blend proportions at 5 levels and extrusion cooking temperature at two levels) was used in this study. Blend proportions: C0 (control): 100:0:0; C1:50:25:25; C2:54.5:24:21.5; C3:50:30:20; and C4:54.5:26.5:19 for OFSP: Amaranth Seeds: Soybean flour, respectively, and extrusion cooking end barrel temperature (70-90ºC) were investigated. The effect of blend proportions and extrusion cooking temperature on the physicochemical and sensory qualities of extruded ready-to-eat baby foods was studied. The screw speed, feed moisture content and die temperature used in this experiment were identified during the preliminary trial stage. The following model was used:

$$Y_{ijk}= \mu+\alpha_i+\beta_j+(\alpha\beta)_{ij}+\varepsilon_{ijk}$$

Where: Y_{ijk}= observation k in level i of factor A and level j of factor B**,** μ = The grand mean, α_i= Effect due to blending, β_j= Effect due to extrusion temperature, $(\alpha\beta)_{ij}$= Interaction between blend proportions and temperature, and ε_{ijk} = Random error.

Determination of moisture and dry matter content

Dry matter content was determined by oven method 934.01 of AOAC (2000), in which 2 g of sample was measured, placed on a drying dish, capped and maintained at 95-100ºC under pressure ≤100 mm Hg (ca 5 h). The moisture content was estimated using the loss on drying (LOD) (Equation 1). The dry matter content was calculated from equation 2.

$$\text{LOD}\ (\%) = \text{Moisture}\ (\%) = 100 \times \frac{\text{Weight loss on drying (g)}}{\text{Weight of sample (g)}} \quad (1)$$

$$\text{Dry matter}\ (\%) = 100 - \%\ \text{LOD} \quad (2)$$

Determination of crude protein

The crude protein content was determined by the micro-Kjeldahl AOAC 920.53 method (2010). Two grams of samples were placed in the Kjeldahl flask. Anhydrous sodium sulfate (5 g of Kjeldahl catalyst) was added to the flask. Concentrated H_2SO_4 (25 ml) was added with a few boiling samples. The flask was heated in the fume chamber until the sample solution became clear. The sample solution was allowed to cool to room temperature, then transferred into a 25 ml volumetric flask and made up to volume with distilled water. The distillation unit was cleaned, and the apparatus was set up. A solution of 2% boric acid (5 ml) with a few drops of methyl red indicator was introduced into a distillate collector (100 ml conical flask). The conical flask was placed under the condenser. Then 25 ml of sample digest was pipetted into the apparatus and washed down with distilled water. A solution of 60% sodium hydroxide (5 ml) was added to the digest. The sample was heated until 100 ml of distillate was collected in the receiving flask. The content of the receiving flask was titrated with 0.049M H_2SO_4 to a pink-coloured endpoint. A blank with filter paper was subjected to the same procedure and the per cent total nitrogen and crude protein were calculated as from Equations 3 and 4.

$$\text{TN (\%)} = \frac{(\text{Title value} - \text{Blank})}{\text{W1}} \times \text{N. of acid} \times \text{N}_2 \text{ ------------ (3)}$$

$$\text{Crude Protein (\%)} = \text{\% Total Nitrogen} \times 6.25 \text{ --------- (4)}$$

Nitrogen factor = 6.25

Where TN = Total Nitrogen; W1 = Weight of sample; N. of acid = Normality of acid of acid.

Determination of crude fat content

This was determined using the Soxhlet extraction with petroleum ether by AOAC 920.39 method (2010). A 500 ml capacity round bottom flask was filled with 300 ml petroleum ether and fixed to the soxhlet extractor. Two grams of sample were placed in a labelled thimble. The extractor thimble was sealed with cotton wool. The heat was applied to reflux the apparatus for 6 hrs. The thimble was removed with care. The petroleum ether was recovered for reuse. When the flask was free of ether, it was removed and dried at 105°C for 1 hr in an oven (Fulton, Model NYC-101 oven). The flask was cooled in desiccators and weighed. The fat content was calculated from Equation 5.

$$\text{Fat (\%)} = \frac{\text{Weight of fat}}{\text{Weight of sample}} \times 100 \qquad (5)$$

Determination of total ash content

Ash content was determined by muffle furnace at 550°C for 12 h with AOAC method 923.03 (2010). Two grams of samples were placed in a silica dish which was ignited, cooled, and weighed. The dish and the sample were ignited first gently and then at 550°C in a muffle furnace (Heraeus, Elisters 2000 Limited, Netherland) until white or grey ash was obtained. The dish and content were cooled in a desiccator and weighed. The total ash content was calculated from Equation 6.

$$\text{Total Ash Content (\%)} = \frac{W_3 - W_1}{W_2 - W_1} \times 100 \qquad (6)$$

Where, W_1= weight of the dish, W_2= weight of dish + sample before ashing, W_3= weight of dish + sample after ashing.

Determination of crude fibre

The crude fibre of ready-to-eat baby foods was determined by the method described by Abifarin *et al*. (2020) using ANKOM Fiber Analyzer (Model: A220, Serial number: A220220240, ANKOM Technology, USA). Briefly, 1 g of the powdered sample was measured, placed in a filter bag, and then put in a bag suspender. The bag suspender was inserted and the system was closed. The samples were dissolved in 100 ml of 1.25% H_2SO_4, and boiled for 30 mins. The system then automatically solubilizes and filtered the samples under pressure, and the residue was washed with boiling water. This residue was then dissolved in 100 ml of 1.25% NaOH solution and boiled for 30 mins. The final residue was then dried at 100°C and measured after cooling in a desiccator. After that, the final residue was incinerated for 5 hours in a muffle furnace at 550°C, cooled in a desiccator, and measured again. This was expressed as a percentage weight of the original sample taken for analysis. The crude fibre content was estimated as from Equation 7.

$$\text{Crude fibre (\%)} = \frac{W_1 - W_2}{W_3} \times 100 \qquad (7)$$

Where: W_1 is the oven-dried sample, W_2 is the weight of sample incineration, W_3 is the weight of the sample taken.

Determination of carbohydrate

The total carbohydrate content was determined by the difference method described by Gbadebo and Ahmed (2021).

Determination of energy value and energy-to-protein ratio

The calorific value and energy-to-protein ratio were determined using the method of de Menezes *et al*. (2015).

Determination of energy and nutrient density

Energy and nutrient contents of extruded ready-to-eat foods were transformed into energy density (kcal/g) and nutrient density (g/100 kcal) as described in the WHO/UNICEF guideline (1998) and Marcel *et al*. (2021). Energy density was calculated by dividing the energy contents of the ready-to-eat baby foods by 100 while nutrient density was determined by dividing the targeted nutrient content of the ready-to-eat baby foods by its energy content and then multiplying by 100.

Determination of vitamin A

The beta-carotene was determined by UV/Visible spectrophotometer according to Rodriguez-Amaya and Kimura (2004) method with modification. Vitamin A in retinol activity equivalent was converted following the method of Trumbo *et al*. (2003).

Determination of minerals

Determination of minerals (Ca, Fe, Mg, Mn, Zn, and Cu) were carried out by Atomic Absorption Spectrophotometry

(Model AA-6300, Serial No A30524300916 SA, Shimadzu Corporation, Japan) (AACC International, 2010) Method 40 - 70.01 and Method 40-71.01 for K and Na.

Determination of phytate

Phytates were determined using an available commercial assay kit, K-PHYT 05/2019 (Megazyme International, Ireland) with modifications. A sample of 5 g was extracted for 30 mins with 100 ml 0.5 N HCl using a magnetic stirrer. The aliquot (10 ml) of the supernatant was transferred to a 40-ml conical centrifuge tube after centrifugation at 3000×*g* for 10 mins. The phytic acid in the samples was precipitated quickly with 4 ml $FeCl_3$ into an aliquot in the centrifuge tubes, and the contents were heated in a boiling water bath for 45 mins, yielding a clear supernatant after 30 mins. The contents were centrifuged at 3000×*g* for 15 mins, and the clear supernatant was carefully decanted. The precipitate was washed twice, first in 25 ml HCl, then in boiling water for 10 mins before centrifugation (3000×*g*, 10 mins). The precipitate was washed once again with distilled water. The precipitate was mixed with 2 ml of 2% NaOH and dispersed in a few millilitres of water. The volume was reduced to around 30 ml with distilled water and then cooked for 30 mins in boiling water. Filtration was done on fairly retentive paper when it was hot (quantitatively). The filtrate was discarded after washing the precipitate with 70 ml of hot distilled water. The precipitate on the filter paper was transferred and dissolved into a 100 ml volumetric flask containing an acid combination of equal amounts (1 ml) of conc. H_2SO_4 and 65% $HClO_4$ solution/0.6 ml of ascorbic acid molybdenum blue. The paper was rinsed with distilled water, the contents were cooled to room temperature, and the volume was increased to 100 ml. A sample of 5 ml was transferred to a new 100-ml volumetric flask and diluted with distilled water to about 70 ml. With distilled water, the volume finally reached 100 ml. Using a spectrophotometer and distilled water as a blank, the absorbance of the sample and standard was measured quickly (within 1 min) at 520 nm. The phytate content was calculated using a potassium dihydrogen phosphate standard curve, and the result was expressed in mg/100g.

Determination of oxalate

Oxalate content was determined by the method described by Fategbe *et al*. (2021) with slight modifications, where 5 g of the sample was suspended in 250 ml of distilled water in a 300 ml flask and 60 ml of 30% HCl was added to the flask and allowed to digest for 1 h, then filtered. Before heating to 90°C in a water bath, the pH of the mixture was adjusted by adding concentrated NH_4OH solution until the colour of the test solutions changed from salmon pink to a pale yellow. After that, it was filtered and cooled (to remove ferrous ion precipitates). The filter was heated to 90°C again, and 10 ml of 5 % $CaCl_2$ solution was added with steady stirring, and then allowed to cool before being kept overnight at 5°C in the refrigerator. Solutions were then centrifuged at 3000×*g* for 5 mins, supernatants removed, and precipitates dissolved in 10 ml of 20% H_2SO_4 solution and diluted to a total volume of 100 ml. Twenty-five ml of each filtrate was heated until close to the boiling point, then titrated against 0.05 M standardized $KMnO_4$ until a faint pink colour developed and remained for 30 s. The oxalate content was estimated by considering that 1 ml of 0.05M $KMnO_4$ solution correspondent to 0.00225 g anhydrous oxalic acid (Equation 8).

$$\text{Oxalate (mg/g)} = \frac{\text{Title Value}\times 100\times 0.00225}{\text{Weight of Sample}} \qquad (8)$$

Determination of saponins

Saponin content was determined by the method described by Abifarin *et al*. (2020), in which 5 g of the sample was measured into a beaker containing 200 ml of 20% ethanol. The solution was heated in a hot water bath for 4 hrs at 55°C and filtered, and the residue was re-extracted with another 50 ml of 20% ethanol. The filtrates were mixed and concentrated to 20 ml over the hot water bath at 90°C. The solution obtained was transferred into a 250 ml separating funnel containing 20 ml of diethyl ether. The aqueous layer was collected where 20 ml of n-butanol was added to it, and then washed thrice with 10 ml of 5 % sodium chloride. The ether layer was thrown away. The mixture was oven dried to constant weight, and the percentage saponin content of the sample was calculated from equation 9:

$$\text{Saponin (\%)} = \frac{\text{A}-\text{B}}{\text{Sw}} \times 100 \qquad (9)$$

Where, A = Mass of flask and extract, B = Mass of an empty flask and Sw = Sample weight

Determination of expansion ratio

Extrudates were measured using a digital electronic Vernier calliper (Mitutoyo Digital Calliper, Japan) with a 0.01- mm accuracy. Fifteen measurements were taken for each sample, and the average diameter was calculated. To determine the expansion ratio (ER), the diameter of the extrudate was divided by the die diameter as shown in equation 10 (Nagaraju *et al*., 2021).

$$\text{ER} = \frac{\text{Extrudate Diameter}}{\text{Die Diameter}} \qquad (10)$$

The sectional expansion ratio (SER) for the extrudates may also be calculated by dividing the square of extrudate diameter (Ed) by the square of die diameter (Dd) as presented in equation 11.

$$\text{SER} = \frac{\text{Ed}^2}{\text{Dd}^2} \qquad (11)$$

Determination of bulk density

The bulk density of extrudate was calculated using the method described by Molla and Zegeye (2020).

Sensory evaluation

Acceptance test and sixty-five untrained panellists were used to assess the sensory quality of extruded ready-to-eat baby foods. The breastfeeding mothers and mothers who have children under-five years of age evaluated RTE baby foods individually in testing booths under controlled conditions and without distraction. The panellists were individually given a consent form and a hedonic assessment form with instructions, and the attributes that were assessed, were based on appearance, colour, aroma, taste, texture, and overall acceptability using a 5-point hedonic scale (Singh-Ackbarali and Maharaj, 2014).

Data analysis

The data for proximate composition, minerals, vitamin A content, anti-nutrients, physical properties, and sensory qualities were statistically analyzed using SAS version 9.4 TS Level 1M6 (SAS Institute Inc.). Basic statistical measures and goodness-of-Fit tests were carried out for the normality distribution of data using PROC UNIVARIATE while the Levene test was conducted for standard homogeneity of variance using HOVTEST=LEVENE. Data were presented as mean ± standard deviation of triplicate determination. Mean values were analyzed using the analysis of variance (ANOVA), and the effect of blend proportions and extrusion cooking temperature was carried out using PROC GLM and mean separations were tested using Tukey's Studentized Range (HSD) Test at a 5 % significance level.

RESULTS AND DISCUSSION

The nutrient density of ready-to-eat baby foods

After statistical analysis, it was discovered that all tested parameters differ significantly ($p<0.05$) among samples. The nutrient density of the extruded ready-to-eat baby foods is shown in Table 1 and its graphical presentation is illustrated in Figure 1. The protein density of extruded ready-to-eat baby foods varied from 0.78 to 4.26 g/100 kcal.

This falls within the results (3.50-4.79 g/100kcal) reported by Tenagashaw *et al*. (2017) for complementary foods formulated from a blend of teff, soybean, and orange-fleshed sweet potato but also confirms well with the level (<5.5 g/100 kcal) recommended for young children (1-3 years old) according to Codex standard. When the food surpasses the recommended protein-energy (PE) ratio, protein nutrition difficulties will be caused by insufficient food rather than a lack of protein. PE ratios in most typical foods range between 10% and 15%. Human breast milk has a PE ratio of around 7%, which is sufficient for fast development in the early months of childhood.

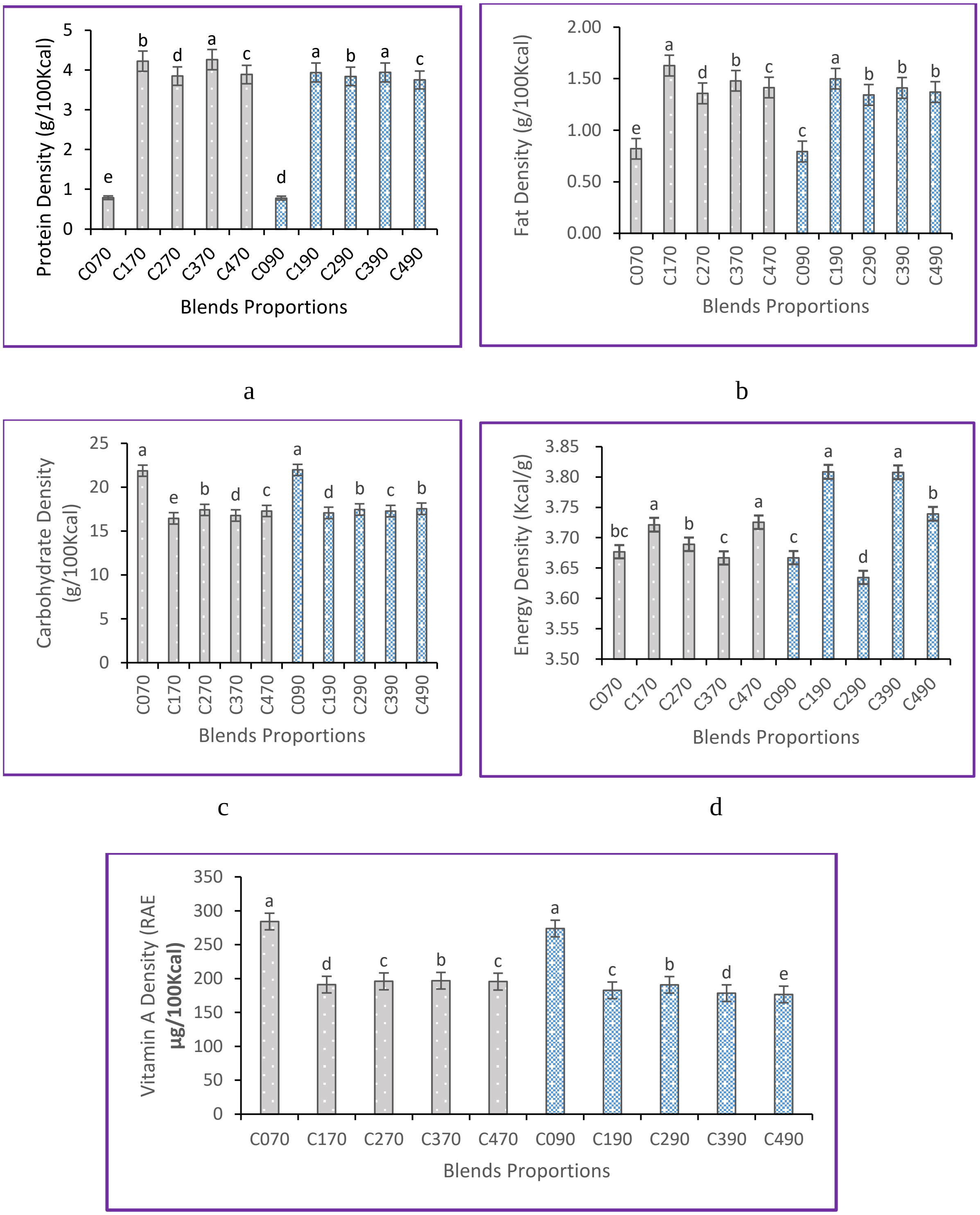
The total fat density ranged from 0.79 to 1.63 g/100 kcal. This is in the agreement with the range 1.26-1.66 g/100 kcal reported by Tenagashaw *et al*. (2017) for complementary foods formulated from a blend of teff, soybean, and orange-fleshed sweet potato. This is below the maximum level of lipid (3.3 g/100 kcal) required from processed cereal-based foods for young children by Codex Alimentarius standard. The codex also recommends a minimum of 4.4 g/100kcal and a maximum of 6.0 g/100 kcal of total fat density for infant formulas with no guidance on upper levels.

The carbohydrate density ranged from 16.45 to 21.97 g/100 kcal. Similar findings (18.22-20.05 g/100 kcal) were reported by Tenagashaw *et al*. (2017) for complementary foods formulated from a blend of teff, soybean, and orange-fleshed sweet potato. There is no recommended level of carbohydrate density for processed young children's foods by the Codex Alimentarius Commission. However, it recommends carbohydrate density for infant formulas to fall within 9.0-14.0 g/100 kcal though there is no guidance on upper levels for carbohydrate density. The recommended dietary allowance of carbohydrates is 80-95 g/day for infants, and 130 g/day for children (Whitney and Rolfes, 2019).

The energy density ranged from 3.63 to 3.81 kcal/g. The codex recommends that the energy density of cereal-based foods should not be less than 0.8 kcal/g for infant and young children formulas. The vitamin A density ranged from 176.57 to 284.13 RAE µg/100 kcal. There are within and above the range of 60-180 RAE µg/100 kcal of vitamin A recommended by codex standard for young children. There is no guidance on upper levels of vitamin A provided by the Codex Alimentarius Commission for young children but a tolerable upper intake level (UL) of 3000 µg/day of preformed vitamin A has been established for pregnancy and lactating mothers, 600 µg/day for infants and children aged 1-3 years old, 900 µg/day for children aged 4-8 years old and 1700 µg/day for children aged 9-13 years old (Gropper *et al*., 2022).

Nutritional contents of Ready-To-Eat baby foods

The results from nutritional contents of ready-to-eat baby foods are given in Table 2 and a significant difference ($p<0.05$) among samples was observed. In addition, blend proportions and extrusion cooking temperature significantly ($p<0.05$) affected the nutritional composition of ready-to-eat baby foods. The dry matter content, crude



a

b

c

d

e

Figure 1. Graphs representing protein (a), fat (b), carbohydrate (c), energy (d), and vitamin A density of extruded ready-to-eat baby foods. The means bars having different letters are significantly different at $p < 0.05$. C070-C470, are blend proportions extruded at 70°C while C090-C490, are blend proportions extruded at 90°C.

protein content, crude fibre content, total ash content, crude fat content, carbohydrate content, energy value, energy-to-protein value and vitamin A content of ready-to-eat baby foods are shown in Table 2.

Table 1. Nutrient and energy density of extruded ready-to-eat baby foods.

Blends Proportions	ET (ºC)	Protein Density (g/100Kcal)	Fat Density (g/100Kcal)	Carbohydrate Density (g/100Kcal)	Energy Density (Kcal/g)	Vitamin A Density (RAE µg/100Kcal)
C0	70	0.79 ± 0.00^{g}	0.82 ± 0.00^{e}	21.88 ± 0.01^{a}	3.68 ± 0.00^{cd}	284.13 ± 0.17^{a}
C1	70	4.22 ± 0.00^{b}	1.63 ± 0.00^{a}	16.45 ± 0.01^{g}	3.72 ± 0.00^{b}	190.91 ± 0.30^{e}
C2	70	3.85 ± 0.01^{e}	1.36 ± 0.01^{cd}	17.41 ± 0.01^{bc}	3.69 ± 0.01^{c}	195.87 ± 0.31^{cd}
C3	70	4.26 ± 0.02^{a}	1.48 ± 0.01^{b}	16.77 ± 0.02^{f}	3.67 ± 0.01^{d}	196.82 ± 0.39^{c}
C4	70	3.89 ± 0.01^{d}	1.41 ± 0.03^{c}	17.29 ± 0.06^{cd}	3.73 ± 0.01^{b}	195.49 ± 0.15^{d}
C0	90	0.78 ± 0.00^{g}	0.79 ± 0.01^{e}	21.97 ± 0.02^{a}	3.67 ± 0.00^{d}	273.86 ± 0.43^{b}
C1	90	3.94 ± 0.01^{c}	1.50 ± 0.06^{b}	17.06 ± 0.12^{e}	3.81 ± 0.01^{a}	182.63 ± 0.43^{g}
C2	90	3.84 ± 0.00^{e}	1.34 ± 0.01^{d}	17.46 ± 0.03^{b}	3.63 ± 0.00^{e}	190.57 ± 0.32^{e}
C3	90	3.94 ± 0.02^{c}	1.41 ± 0.01^{c}	17.27 ± 0.02^{d}	3.81 ± 0.01^{a}	178.30 ± 0.69^{g}
C4	90	3.75 ± 0.01^{f}	1.37 ± 0.01^{cd}	17.54 ± 0.02^{b}	3.74 ± 0.01^{b}	176.57 ± 0.22^{h}
Codex Standard		<5.5	4.4-6.0	9.0-14.0	>0.8	60-180

Data are indicated in triplicate values as the mean ± standard deviation. Mean values with different superscript letters in the same column are significantly different ($p \leq 0.05$). Where BP is the blend proportions, ET: Extrusion temperature; C0 (control): 100:0:0; C1:50:25:25; C2:54.5:24:21.5; C3:50:30:20; and C4:54.5:26.5:19 for OFSP: Amaranth Seed: Soybean flour, respectively.

Table 2. Nutritional composition of Ready-To-Eat baby foods.

BP	ET (ºC)	DM (%)	Crude protein (%)	Crude fibre (%)	Crude ash (%)	Crude fat (%)	CHO (%)	EV (kcal/100g)	ETPR (Kcal/g of Protein)	Vitamin A (RAE µg/100g)
C0	70	94.55±0.15^{b}	2.90±0.01^{g}	3.61±0.06^{e}	4.60±0.04^{e}	3.02±0.01^{g}	80.43±0.08^{a}	367.68±0.41^{cd}	126.93±0.14^{b}	1044.70±0.55^{a}
C1	70	92.68±0.10^{d}	15.72±0.03^{a}	4.93±0.01^{ab}	4.75±0.01^{d}	6.05±0.02^{a}	61.23±0.09^{f}	372.13±0.42^{b}	23.67±0.02^{f}	710.45±0.32^{e}
C2	70	93.29±0.20^{c}	14.20±0.06^{d}	5.04±0.03^{a}	4.80±0.01^{cd}	5.01±0.02^{ef}	64.24±0.17^{d}	368.91±0.69^{c}	25.97±0.08^{d}	722.59±0.32^{d}
C3	70	95.47±0.26^{a}	15.62±0.05^{b}	4.71±0.06^{d}	4.63±0.01^{e}	5.42±0.04^{c}	61.49±0.21^{e}	366.67±0.86^{d}	23.47±0.13^{f}	721.67±0.32^{d}
C4	70	94.15±0.14^{b}	14.48±0.04^{d}	4.78±0.05$^{\mathbf{bcd}}$	4.66±0.01^{e}	5.27±0.10^{cd}	64.41±0.28^{cd}	372.55±0.28^{b}	25.72±0.05^{de}	728.29±0.32^{c}
C0	90	94.58±0.07^{b}	2.85±0.01^{g}	3.39±0.05^{f}	4.85±0.02^{c}	2.91±0.03^{g}	80.58±0.05^{a}	366.70±0.37^{d}	128.67±0.58^{a}	1004.23±0.84^{b}
C1	90	95.41±0.30^{a}	15.00±0.03^{c}	4.75±0.12^{cd}	4.96±0.02^{b}	5.71±0.23^{b}	64.99±0.40^{c}	380.84±0.78^{a}	25.39±0.08^{e}	695.55±0.32^{f}
C2	90	92.61±0.06^{d}	13.96±0.01^{f}	4.92±0.04^{abc}	5.39±0.07^{a}	4.88±0.05^{f}	63.47±0.10^{e}	363.45±0.50^{e}	26.04±0.03^{d}	692.60±0.55^{g}
C3	90	91.87±0.13^{e}	15.00±0.02^{c}	4.66±0.04^{d}	4.66±0.01^{e}	5.37±0.05^{c}	65.78±0.22^{b}	380.77±1.21^{a}	25.38±0.11^{e}	678.92±0.55^{h}
C4	90	93.61±0.17^{c}	14.03±0.01^{f}	4.65±0.05^{d}	4.75±0.02^{d}	5.12±0.03^{de}	65.60±0.15^{b}	373.92±0.62^{b}	26.65±0.06^{c}	660.23±0.32^{i}

Data are indicated in triplicate values as the mean ± standard deviation. Mean values with different superscript letters in the same column are significantly different ($p \leq 0.05$). Where BP is the blend proportions. ET: Extrusion temperature, CHO: carbohydrate, EV: energy value, ETPR: Energy-to-protein ratio, C0: Orange-fleshed sweet potato (OFSP) as control; C1:50:25:25; C2:54.5:24:21.5; C3:50:30:20; C4:54.5:26.5:19 for OFSP: Amaranth seed: soybean, respectively.

Dry matter content and moisture content of ready-to-eat baby foods

The dry matter content of extruded ready-to-eat baby foods ranged from 91.87 to 95.47% which indicates 4.53 to 8.13% of moisture content. The moisture content is a measure of the water content available in food and is an index of the storage stability of the noodles and also an indication of the dry matter in that food (Adegunwa *et al*., 2014). The results are slightly above the results (1.86 to 5.2%) reported by Oke *et al*. (2022) for noodles from wheat-tigernut pomace flour blends and 5.9 to 6.0% reported by Osibanjo *et al*. (2022) for extrudates from maize/soybean blends but confirm well with the results (3.10± 0.001 to 7.02± 0.003 %) reported by Umoh and Iwe (2022), for the extruded aerial yam-soybean flour blends. The moisture content of extruded ready-to-eat baby foods was typically lower than the 14% permitted by the Codex Alimentarius Commission (CAC) for non-fried noodles and less than 10% for fried noodles (CAC, 2019), which makes it appealing for long-term storage. The low moisture content of extruded ready-to-eat baby foods makes them less susceptible to microbial attack and would have longer shelf-life stability as well as the decreased risk of physical and chemical reactions that might deteriorate food quality.

Protein contents of ready-to-eat baby foods

Proteins are a common class of biomolecules that are essential to the food industry as elements to give food products flavour, texture, and taste as well as nutritional and functional qualities (Aryee *et al*., 2018). The protein content of extruded ready-to-eat baby foods ranged from 2.85 to 15.72%. The results are close to the values (12.5 to 21.24%) reported by Osibanjo *et al*. (2022) for extrudates from maize/soybean blends and slightly below the results (16.38 to 33.46%) obtained by Sobowale *et al*. (2021) for extruded cocoyam noodles. The findings are also above the trends (2.91 to 4.28 %) reported by Oke *et al*. (2022) for noodles from wheat-tiger nut pomace flour blends and slightly above the results (4.38±1.24 to 13.13±1.24%) reported by Maximus (2019) for ready-to-eat breakfast cereals from blends of sorghum, pigeon pea, and mango flour. The lowest protein content (2.85%) was observed in the control sample while blend C1 and C3 yielded high protein content of 15.72% and 15.62 %, respectively. This may be the result of the incorporation of amaranth seeds and soybean flour which have a high quantity of protein at 19.80% and 31.53%, respectively as observed from our previous research. These high values of protein in extruded ready-to-eat baby foods indicate that they could be a potentially rich source of protein required by humans for proper growth and development. All the extruded ready-to-eat baby foods meet the recommended dietary allowance of protein (13 g/day) for children aged 1-3 years except the control sample (Stathers *et al*., 2018).

The extrusion cooking of plant-based proteins improves protein digestibility which is primarily linked to the inactivation and destruction of anti-nutrients compounds present in foods and the thermal denaturation of protein. Anti-nutrients may have a detrimental impact on human health by lowering mineral and protein bioavailability and protein digestibility (Ndidi *et al*., 2014). In addition, further changes in protein quality (amino acid profile) and protein functionality (texturization and solubility) may occur for various extrusion cooking conditions (Gulati *et al*., 2020).

Fat contents of ready-to-eat baby foods

The fat content of extruded ready-to-eat baby foods ranged from 2.91 to 6.05% and fell within the results (2.47 to 8.98%) reported by Sobowale *et al*. (2021) for extruded cocoyam noodles, 1.24 to 5.14% reported by Oke *et al*. (2022) for noodles from wheat-tiger nut pomace flour blends, and compared well to the results (3.08±1.24 to 5.88±0.00 %) found by Maximus (2019) for ready-to-eat breakfast cereals from blends of sorghum, pigeon pea, and mango flour. Fats have an important part in providing flavour, lubricity, and texture to foods, as well as contributing to the perception of satiety after consumption (Türkay and Şahin-Yeşilçubuk, 2017). During extrusion cooking, low quantities of lipids as low as 5% tend to stabilize Specific Mechanical Energy (SME) and minimize glassiness in extrudates. However, high lipid concentrations reduce SME by increasing lubricity inside the extruder barrel and reducing expansion (Singh *et al*., 2007). From a nutritional perspective, lipids tend to react with starch and protein which results in the formation of starch-lipid complexes and lipid-protein complexes, respectively. Lipids act as a plasticizer and also impart adhesive texture. Higher temperatures would inactivate lipase and lipoxygenase activity and thus, reduce the development and oxidation of fatty acids (Mathad *et al*., 2022).

Total ash contents of ready-to-eat baby foods

The ash content of extruded ready-to-eat baby foods ranged from 4.60 to 5.39%. The results are above the results (1.0 to 1.75%) reported by Oke *et al*. (2022) for noodles from wheat-tiger nut pomace flour blends and 2.15±0.35 to 4.15±0.35% found by Maximus (2019) for ready-to-eat breakfast cereals from blends of sorghum, pigeon pea, and mango flour but confirm well with the range (4.03± 0.002 to 5.90± 0.002%) reported by Umoh and Iwe (2022), for the extruded aerial yam-soybean flour blends. The high values for ash content are an indication that extruded ready-to-eat baby foods from OFSP, amaranth seeds, and soybean flour blends have a potentially rich source of minerals.

Fibre contents of ready-to-eat baby foods

The crude fibre content of extruded ready-to-eat baby foods ranged from 3.39 to 5.04%. The results are below the trends (5.78 to 14.81%) reported by Oke *et al*. (2022) for noodles from wheat-tiger nut pomace flour blends but fall within the results (3.80±1.25 to 13.50±0.25%) reported by Maximus (2019) for ready-to-eat breakfast cereals from blends of sorghum, pigeon pea, and mango flour, and confirm well with the trends (2.70± 0.001 to 4.67± 0.003%) reported by Umoh and Iwe (2022), for the extruded aerial yam-soybean flour blends. The high value of fibre content is an indication that the extruded ready-to-eat baby foods from OFSP, amaranth seeds, and soybean flour blends are a potentially rich source of dietary fibre, which is important for the proper flow of food through the digestive tract and aids in the prevention of obesity, diabetes, colon cancer, and other conditions affecting the human gastrointestinal tract.

Carbohydrate contents of ready-to-eat baby foods

The carbohydrate content of extruded ready-to-eat baby foods ranged from 61.23 to 80.58%. The results confirm well with the trends (73.23 to 83.9%) reported by Oke *et al*. (2022) for noodles from wheat-tiger nut pomace flour blends and fall within the values (50.65±0.34 to 77.13±1.8%) obtained by Maximus (2019) for ready-to-eat breakfast cereals from blends of sorghum, pigeon pea, and mango flour. The results compared well to the results (68.95 to 77.61%) reported by Osibanjo *et al*. (2022) for extrudates from maize/soybean blends. The high range of values for carbohydrate content is an indication that extruded ready-to-eat baby foods from OFSP, amaranth seeds, and soybean flour blends is a potentially rich source of energy. The high value of the carbohydrate contents of extruded ready-to-eat baby foods may be attributed to the OFSP substitution. On the other hand, few changes occur during the extrusion process, including the degradation of granular structure, the disruption of glycosidic bonding, and the creation of new molecular interactions (Agarwal and Chauhan, 2019).

Energy contents of ready-to-eat baby foods

Energy values of extruded ready-to-eat baby foods ranged from 363.44 – 380.84 kcal/100g. The results are in agreement with the values (360.69 to 391.88 kcal/100g) reported by Awofadeju *et al*. (2021) for an extruded ready-to-eat breakfast snack and 362.59 to 371.50 kcal/100g reported by Edima-Nyah *et al*. (2020) for breakfast cereals produced with yellow maize, soybean, and banana blends. In addition, the results are slightly below the value (387.89 kcal/100g) reported by Naseer *et al*. (2021), for extrudate almond- pearl millet (APM) based snack but close to the range (383.58 to 409.12 kcal/100 g) reported by Gemede (2020) for complementary foods formulated from maize, pea, and anchote flours. The high energy content observed in this study may be the result of the carbohydrate, fat, and protein content of extruded ready-to-eat baby foods. Energy is necessary to maintain the body's different processes, such as breathing, circulation, physical work, and protein synthesis.

Energy-to-protein ratio of ready-to-eat baby foods

Energy-to-protein ratio of extruded ready-to-eat baby foods varied from 23.47 to 26.65 kcal/g of protein except for 126.93 to 128.67 kcal/g of protein from the control sample. The highest energy-to-protein ratio observed in this study could be the result of the low protein content of the control sample which is OFSP. Studies have demonstrated the importance of the energy-to-protein ratio in broiler growth to maximize the use of amino acids and energy. Lean muscle can result from a diet that has a lower energy-to-protein ratio and higher feed intake. However, a diet with a higher energy-to-protein ratio can result in lower feed intake and higher energy retention as fat (Musigwa *et al*., 2021).

Vitamin A contents of ready-to-eat baby foods

Vitamin A content of extruded ready-to-eat baby foods ranged from 660.23 -to 1044.70 RAE µg/100g and a significant ($p<0.05$) difference was observed among samples. The results obtained from this study are in agreement with the results (0.00-8193 RAE µg/100 g) reported by Kure *et al*. (2021) for bread from wheat and orange-fleshed sweet potato (flour, starch, and non-starch residue flour) blends. Furthermore, the results are within the range (370-2064±17 RAE µg/100g) reported by Adetola *et al*. (2020), for complementary foods from OFSP, soybean, and carrot flour blends. The highest value of vitamin A was observed in the control sample. This may be due to the high content of vitamin A present in OFSP flour. Vitamin A is an important nutrient that is necessary for immunological function. It is commonly referred to as retinol since it releases pigment in the retina of the eye (Kure *et al*., 2021). Vitamins are a minor but necessary component of the diet. Deficiencies in these micronutrients can disrupt normal human growth, maintenance, and functioning, leading to various diseased situations. Inadequate vitamin intake might result from an imbalanced diet or vitamin losses caused by processing (Gulati *et al*., 2020). A lack of vitamin A has been linked to a decrease in lymphocytes, natural killer cells, and antigen-specific immunoglobulin responses. Vitamin A is necessary for appropriate vision, gene expression, cellular differentiation, morphogenesis, growth, and immunological function (Institute of Medicine, 2001).

One of the most promising plant sources of beta-carotene, pro-vitamin A, has been discovered to be orange-fleshed sweet potatoes. For young children, a 100 to 150 g portion of boiling orange-fleshed sweet potato tubers can meet their daily vitamin A needs and prevent blindness (Mitra, 2012). Apart from infant and young children, the extruded ready-to-eat baby foods meet the recommended daily intake (770 RAE µg/day) of vitamin A for pregnant women. The recommended dietary allowances for vitamin A are 400-500 RAE RAE µg/day for infants, 300 to 400 for children, and 1300 RAE µg/day for lactating mothers (Gropper *et al*., 2022). The stability of vitamins during extrusion cooking is dependent on (a) processing factors such as temperature, residence time, screw speed, pressure, feed rate, and screw configuration, and (b) the source of the vitamin, chemical structure, and interactions with other flour components (Riaz *et al*., 2009).

Effect of blend proportions and extrusion on the nutritional composition of baby foods

The extrusion cooking temperature and blend proportions significantly ($p<0.05$) affected the nutritional composition of extruded ready-to-eat baby foods. Considering extrusion cooking at 70°C, the moisture content, carbohydrate content, energy value, energy-to-protein value, and vitamin A content of extruded ready-to-eat baby foods were significantly ($p<0.005$) affected by extrusion cooking and blend proportions except for blend C1 and C2 in terms of energy-to-protein value (Table 3). The crude protein content, fibre content, ash, and fat content were not significantly ($p>0.05$) affected by extrusion cooking and blend proportions though changes occurred. The extrusion cooking at 90°C, on the other hand, significantly ($p<0.05$) affected the moisture content, crude protein content, carbohydrate content, energy value, energy-to-protein value, and vitamin A content of extruded ready-to-eat baby foods in all tested samples. However, only fat content was not significantly ($p>0.05$) affected by extrusion cooking and blend proportions in all samples. Blend C2 and C4 were significantly ($p<0.05$) affected by extrusion cooking and blend proportions in terms of total ash content. The extrusion cooking significantly ($p<0.05$) reduced vitamin A content by 21.33%, moisture content (59.47%), crude protein content (5.56%), and crude fibre content (3.06%) of extruded ready-to-eat baby foods in all tested samples while an increase of total ash content by 10.44%, carbohydrate content (12.31%), energy value (6.38 %), energy-to-protein value (11.28%) were significantly ($p<0.05$) observed in all tested samples. Jozinović*et al*. (2021) reported similar observations where extrusion cooking causes a loss in protein content and an increase in the total ash content of value-added corn snack products.

In addition, Iwe *et al*. (2001) reported an increase in carbohydrate content and energy value of extruded soy and sweet potato flours upon extrusion cooking. Extrusion cooking and post-extrusion process have been known to reduce heat-labile nutrients, anti-nutrients, and microbial elimination and increase product shelf-life by lowering the moisture content of extrudates. Thermal treatment of food containing protein can result in the breaking of disulfide bonds, unfolding, aggregation, and production of dimers and bigger oligomers of proteins (Aryee *et al*., 2018). On the other hand, the degree of the changes is influenced by moisture content, pressure, temperature, and shearing force (Agarwal and Chauhan, 2019). The increase in the carbohydrate contents of extruded ready-to-eat baby foods could be the result of high temperature, shear, and pressure involved during the extrusion cooking. When starch is extruded, it goes through several structural changes, including melting, gelatinization, and fragmentation (Agarwal and Chauhan, 2019).

Mineral composition of ready-to-eat baby foods

The mineral composition of extruded ready-to-eat baby foods significantly ($p<0.05$) differ among the tested samples (Table 4). The iron content of extruded ready-to-eat baby foods varied from 1.18 to 3.10 mg/100g, zinc content from 0.45 to 0.64 mg/100g, manganese content from 0.31 to 0.90 mg/100g, copper content from 0.60 to 0.97 mg/100g, calcium content from 30.41 to 61.22 mg/100g, magnesium content to 40.52-81.70 mg/100g, sodium content from 31.38 to 41.44 mg/100g and potassium content from 59.06 to 68.18 mg/100g. Extrusion cooking affects the bioavailability of minerals instead of their stability, contrary to vitamins. The quantity of a nutrient that is consumed and absorbed such that it is available for physiological processes is known as bioavailability. Extrusion-based research has primarily employed *in vitro* methods to assess bioavailability since bioavailability is a complex process that is expensive and time-consuming to measure. The outcomes of these methods are sometimes referred to as "bioaccessibility," which is defined as the quantity of an element that can be absorbed and used for physiological processes (Etcheverry *et al*., 2012).

Extrusion cooking parameters affect the mineral-binding elements contained in legumes and grains, such as phytic acid, phenolic compounds, dietary fibres, and proteins, which is the main cause of the variations in mineral bioavailability (Raes *et al*., 2014). Extrusion cooking in this study increased Fe, Zn, Cu, Ca, and Mg. This may be the result of the destruction of anti-nutrients mainly phytate and oxalate in extrusion cooking which are major mineral binding compounds and hence improved mineral bioavailability. Oxalate forms close bonds between oxalic acid and other minerals including calcium, magnesium, sodium, and potassium, thereby forming oxalate salts that block nutrients from being available in the body (Nachbar *et al*., 2000). Phytate acts as a largely negative ion in a large pH range and its existence in food also has a negative effect on the bioavailability of divalent and

Table 3. Effect of blend proportions and extrusion temperature on the nutritional composition of ready-to-eat baby foods.

BP	Statistics	MC	Protein	fibre	Ash	Fat	CHO	EV	ETPV	Vitamin A
Data for ready-to-eat baby foods extruded at 70ºC										
C0	Non-Extruded	10.00±0.00	2.95±0.04	3.66±0.13	4.60±0.19	3.05±0.28	75.73±0.53	349.53±0.65	118.37±1.69	1,162.50±0.17
	Extruded	5.45±0.15	2.90±0.01	3.61±0.06	4.60±0.04	3.02±0.01	80.43±0.08	367.68±0.41	126.93±0.14	1,044.70±0.55
	t-value	51.97	2.40	0.71	0.03	0.22	-15.26	-41.07	-8.75	352.74
	p-value	<0.0001****	0.133^{ns}	0.54^{ns}	0.98^{ns}	0.84^{ns}	0.004^{**}	$<0.0001^{****}$	0.012^{*}	$<0.0001^{****}$
	Change (%)	45.53^{a}	1.92^{a}	1.55^{a}	0.07^{a}	1.22^{a}	5.85^{b}	4.94^{b}	6.75^{b}	11.28^{a}
C1	Non-Extruded	11.33±0.58	15.83±0.31	4.94±0.81	4.75±0.14	6.16±0.19	56.99±0.47	356.56±0.89	22.53±0.49	780.17±0.38
	Extruded	5.45±0.15	15.72±0.03	4.93±0.01	4.75±0.01	6.05±0.02	61.23±0.09	372.13±0.42	23.67±0.02	710.45±0.32
	t-value	11.88	0.64	0.021	0.042	0.932	-15.48	-27.29	-4.083	244.033
	p-value	0.006^{**}	0.59^{ns}	0.99^{ns}	0.97^{ns}	0.449^{ns}	0.003^{**}	0.0002^{***}	0.055^{ns}	<0.0001****
	Change (%)	35.41^{a}	0.72^{a}	0.20^{a}	0.07^{a}	1.71^{b}	6.93^{b}	4.18^{b}	4.84^{b}	9.81^{a}
C2	Non-Extruded	11.10±0.17	14.50±0.50	5.00±0.10	4.83±0.06	5.07±0.12	59.50±0.43	351.61±0.70	24.27±0.89	800.00±0.17
	Extruded	6.71±0.20	14.20±0.06	5.04±0.03	4.80±0.01	5.01±0.02	64.24±0.17	368.91±0.69	25.97±0.08	722.59±0.32
	t-value	28.834	1.021	0.62	0.843	0.883	-17.69	-30.484	-3.321	369.71
	p-value	<0.0001****	0.412^{ns}	0.594^{ns}	0.484^{ns}	0.465^{ns}	0.001^{***}	<0.0001****	0.078^{ns}	<0.0001****
	Change (%)	39.52^{a}	2.09^{a}	0.73^{b}	0.62^{a}	1.20^{a}	7.37^{b}	4.69^{b}	6.56^{b}	10.71^{a}
C3	Non-Extruded	10.34±0.30	15.77±0.25	4.70±0.18	4.64±0.06	5.77±0.25	58.78±0.48	359.49±0.34	22.80±0.38	785.03±0.15
	Extruded	8.13±0.13	15.62±0.05	4.71±0.06	4.63±0.01	5.42±0.04	61.49±0.21	366.67±0.86	23.47±0.13	721.67±0.32
	t-value	11.89	0.967	-0.062	0.306	2.331	-8.983	-13.41	-2.865	310.593
	p-value	0.0003^{***}	0.388^{ns}	0.954^{ns}	0.775^{ns}	0.080^{ns}	0.001^{***}	0.0002^{***}	0.046^{*}	<0.0001****
	Change (%)	21.43^{a}	0.92^{a}	0.14^{b}	0.22^{a}	6.33^{a}	4.40^{b}	1.96^{b}	2.84^{b}	8.78^{a}
C4	Non-Extruded	10.33±0.58	14.68±0.35	4.79±0.01	4.65±0.05	5.38±0.42	60.16±1.04	357.36±0.64	24.35±0.63	801.03±0.15
	Extruded	6.39±0.17	14.48±0.04	4.78±0.05	4.66±0.01	5.27±0.10	64.41±0.28	372.55±0.28	25.72±0.05	728.29±0.32
	t-value	11.325	0.97	0.342	-0.450	0.441	-6.814	-37.644	-3.753	356.56
	p-value	0.0003^{***}	0.387^{ns}	0.750^{ns}	0.676^{ns}	0.682^{ns}	0.002^{**}	<0.0001****	0.020^{*}	<0.0001****
	Change (%)	38.16^{a}	1.38^{a}	0.21^{a}	0.29^{b}	2.09^{a}	6.60^{b}	4.08^{b}	5.35^{b}	9.99^{a}

trivalent mineral ions such as Zn2+, Fe2+ /3+, Ca2+, Mg2+, Mn2+, and Cu2+ in the body (Mueller, 2001).

During extrusion cooking, these phenolic compounds undergo degradation or polymerize-tion, which diminishes their chelating capabilities (Sandberg *et al*., 1987).

Anti-nutrient contents of ready-to-eat baby foods

The anti-nutritional contents of extruded ready-to-eat baby foods and their corresponding composite flour blend significantly (p<0.05) differ among samples (Table 5). The phytate content in the composite flour ranged from 7.49 mg/100g to 10.79 mg/100g) and the highest level was observed in the control sample (C0) which contains orange-fleshed sweet potato flour. The results are in agreement with the values (8.18 to 9.78 mg/100g) reported by Edima-Nyah *et al*. (2020) for breakfast cereals produced with yellow maize, soybean, and banana flour blends. The results are lower than the results

Table 3. Contd.

Data for ready-to-eat baby foods extruded at 90ºC										
C0	Extruded	5.42±0.07	2.85±0.01	3.39±0.05	4.85±0.02	2.91±0.03	80.58±0.05	366.70±0.37	128.67±0.58	1,004.23±0.84
	t-value	113.326	4.299	3.441	-2.166	0.870	-15.865	-39.856	-9.984	318.528
	p-value	<0.0001****	0.013^{*}	0.026^{*}	0.096^{ns}	0.433^{ns}	<0.0001****	<0.0001****	0.001^{***}	<0.0001****
	Change (%)	45.80^{a}	3.63^{a}	7.37^{a}	5.02^{b}	4.93^{a}	6.02^{b}	4.68^{b}	8.01^{b}	15.76^{a}
C1	Extruded	4.59±0.30	15.00±0.03	4.75±0.12	4.96±0.02	5.71±0.23	64.99±0.40	380.84±0.78	25.39±0.08	695.55±0.32
	t-value	17.984	4.71	0.387	-2.551	2.616	-22.547	-35.449	-10.056	296.190
	p-value	<0.0001****	0.009^{**}	0.718^{ns}	0.063^{ns}	0.059^{ns}	<0.0001****	<0.0001****	0.001^{***}	<0.0001****
	Change (%)	59.47^{a}	5.56^{a}	3.71^{a}	4.10^{b}	7.82^{a}	12.31^{b}	6.38^{b}	11.28^{b}	12.17^{a}
C2	Extruded	7.39±0.06	13.96±0.01	4.92±0.04	5.39±0.07	4.88±0.05	63.47±0.10	363.45±0.50	26.04±0.03	692.60±0.55
	t-value	35.387	1.882	1.338	-10.819	2.569	-15.539	-23.927	-3.464	321.591
	p-value	<0.0001****	0.133^{ns}	0.252^{ns}	0.0004^{***}	0.062^{ns}	<0.0001****	<0.0001****	0.026^{*}	<0.0001****
	Change (%)	33.45^{a}	3.89^{a}	1.67^{a}	10.44^{b}	3.83^{a}	6.24^{b}	3.26^{b}	6.80^{b}	15.51^{a}
C3	Extruded	4.53±0.26	15.00±0.02	4.66±0.01	4.66±0.04	5.37±0.05	65.78±0.22	380.77±1.21	25.38±0.11	678.92±0.55
	t-value	25.41	5.236	0.417	-0.612	2.678	-22.983	-29.211	-11.281	320.971
	p-value	<0.0001****	0.006^{**}	0.698^{ns}	0.573^{ns}	0.055^{ns}	<0.0001****	<0.0001****	0.0004^{***}	<0.0001****
	Change (%)	56.20^{a}	5.09^{a}	0.92^{a}	0.43^{b}	7.39^{a}	10.64^{b}	5.59^{b}	10.15^{b}	15.63^{a}
C4	Extruded	5.85±0.14	14.03±0.01	4.65±0.05	4.75±0.02	5.12±0.03	65.60±0.15	373.92±0.62	26.65±0.06	660.23±0.32
	t-value	13.071	3.189	4.919	-3.216	1.042	-8.938	-32.318	-6.284	690.20
	p-value	0.0002^{***}	0.033^{*}	0.008^{**}	0.032^{*}	0.356^{ns}	0.001^{***}	<0.0001****	0.023^{*}	<0.0001****
	Change (%)	43.39^{a}	4.66^{a}	3.06^{a}	2.11^{b}	4.94^{a}	8.29^{b}	4.43^{b}	8.65^{b}	21.33^{a}

Where: C0 (control): 100:0:0; C1:50:25:25; C2:54.5:24:21.5; C3:50:30:20; and C4:54.5:26.5:19 for OFSP: Amaranth Seed: Soybean flour, respectively. *, **, ***, ****, ^{ns}, ^{a}, ^{b} = Significant at $p \leq 0.05$, $p \leq 0.01$, $p \leq 0.001$, $p \leq 0.0001$, Not significant, Loss, Retention, respectively.

of 50 to 420 mg/100g for Kenyan sweet potato varieties in roots (SPK031 and Vitaa, respectively) (Abong *et al*., 2020). In addition, the results are below the values (240±0.02 mg/100g, 300±0.11 mg/100g and 230±0.02 mg/100g) for bread from Kabode, SPK and Yellow sweet potato varieties in Kenya, respectively (Abong *et al*., 2020). The findings confirm well with the results (10 to 12 mg/100g) reported by Olapade and Ogunade (2014) for cream flesh sweet potato and yellow flesh sweet potato flour. The depletion of phytate content during the drying process of raw materials may be the cause of low levels of phytate content in the orange-fleshed sweet potato flour.

The oxalate content in the composite flour ranged from 1.45 to 3.10 mg/100g and a significant difference (p<0.05) was observed among samples. The results are lower than the value (1130 mg/100g) reported by Airaodion *et al*. (2019) for raw cassava mash and 152.52±23.47 mg/100g reported by Abong *et al*. (2020) for Kenspot 5 roots. However, the results are in agreement with the results (3.50 to 8.80 mg/100g) reported by Dako *et al*. (2016) for yellow, white, and orange-fleshed sweet potato varieties and very close to the values (4.23 to 4.66 mg/100g) reported by Fekadu (2014) for processed anchote tubers. The saponin content

Table 4. Mineral composition (mg/100g) of Ready-To-Eat baby foods.

BP	ET(°C)	Fe	Zn	Cu	Mn	Ca	Mg	Na	K
C0	70	1.18 ± 0.00g	0.61 ± 0.00b	0.71 ± 0.01c	0.90 ± 0.01a	30.41 ± 0.37h	40.52 ± 0.04e	41.44 ± 0.15a	68.18 ± 0.12^{a}
C1	70	2.83 ± 0.01c	0.56 ± 0.02cd	0.60 ± 0.00f	0.40 ± 0.00c	59.22 ± 0.07b	80.89 ± 0.01ab	34.44 ± 0.12e	64.51 ± 0.16^{b}
C2	70	1.88 ± 0.00e	0.45 ± 0.00g	0.64 ± 0.01de	0.32 ± 0.00de	50.93 ± 0.32d	78.74 ± 0.20c	40.22 ± 0.02c	61.43 ± 0.01^{c}
C3	70	2.79 ± 0.02c	0.52 ± 0.01e	0.62 ± 0.00e	0.26 ± 0.01f	52.69 ± 0.16c	80.50 ± 0.00b	31.51 ± 0.01f	61.08 ± 0.02^{d}
C4	70	1.82 ± 0.00f	0.46 ± 0.00fg	0.95 ± 0.00b	0.33 ± 0.01d	33.28 ± 0.07f	80.37 ± 0.02b	38.64 ± 0.00d	59.26 ± 0.02^{e}
C0	90	1.19 ± 0.01g	0.64 ± 0.00a	0.72 ± 0.01c	0.87 ± 0.01b	31.67 ± 0.43g	41.85 ± 0.55d	41.04 ± 0.03b	68.03 ± 0.01^{a}
C1	90	2.98 ± 0.01b	0.56 ± 0.00cd	0.64 ± 0.01d	0.39 ± 0.01c	61.22 ± 0.07a	81.55 ± 0.49a	34.44 ± 0.12e	64.35 ± 0.06^{b}
C2	90	2.21 ± 0.01d	0.46 ± 0.00fg	0.65 ± 0.00d	0.31 ± 0.01e	51.59 ± 0.26d	79.41 ± 0.37c	40.24 ± 0.12c	61.41 ± 0.01^{c}
C3	90	3.01 ± 0.01b	0.54 ± 0.00de	0.64 ± 0.01de	0.26 ± 0.00f	53.36 ± 0.67c	81.50 ± 0.00a	31.38 ± 0.06f	61.02 ± 0.02^{d}
C4	90	3.10 ± 0.06a	0.47 ± 0.01d	0.97 ± 0.01a	0.34 ± 0.00d	34.62 ± 0.55e	81.70 ± 0.56a	38.63 ± 0.02d	59.06 ± 0.02^{e}
	RDA (mg/day)	0.27-11* 7-10** 9*** 27****	2-3* 3-5** 12*** 11****	0.2-0.22* 0.34 -0.44** 1.3*** 1****	0.003-0.6* 1.2-1.5** 2.6*** 2.0****	200-260* 700-1000** 1000***,****	30-75* 80-130** 310-320*** 350-360****	120-370* 1000-1200** 1500***,****	400-700* 3000-3800** 5100*** 4700****

Results are indicated in triplicate values as the mean ± standard deviation. Mean values with different superscript letters in the same column are significantly different (p ≤ 0.05). Where BP is the blend proportions, ET: Extrusion temperature; C0 (control): 100:0:0; C1:50:25:25; C2:54.5:24:21.5; C3:50:30:20; and C4:54.5:26.5:19 for OFSP: Amaranth Seed: Soybean flour, respectively.*Infant, **Children, ***Lactating Mothers, ****Pregnancy (Gropper et al., 2022).

in the composite flour ranged from 7.14 to 9.98 mg/100g and a significant difference (p<0.05) was observed among samples. The values are lower than the value of 222 mg/100g reported by Airaodion *et al*. (2019) for raw cassava mash but in agreement with the values (9.30 to 16.23 mg/100g) reported by Edima-Nyah *et al*. (2020) for breakfast cereals produced with yellow maize, soybean, and banana flour blends.

On the other hand, the phytate content of extruded ready-to-eat baby foods varied from 0.47 to 1.79 mg/100g. The results are below the range (323.47 to 428.33 mg/100 g) reported by Tadesse *et al*. (2019) for sorghum-based extruded product supplemented with defatted soy meal flour and the range (64.74 to 72.15 mg/100g) reported by Gemede (2020) for complementary foods formulated from maize, pea, and anchote flours but slightly above to the findings (0.20 to 0.32 mg/100g) reported by Awofadeju *et al*. (2021) for an extruded ready-to-eat breakfast snack.

The results are lower than the range (18 to 37 mg/100g) reported by Fakolujo and Adelugba (2021) for extruded snacks made from acha, jack bean, and pawpaw flour blends but in agreement with the results (0.55 to 1.48 mg/100g) reported by Nkesiga and Okafor (2015) for extruded snacks from yellow maize, soybean and amaranth leaf flour blends. Abubakar *et al*. (2010) reported very close values of 0.86 mg/100g for boiled sweet potato. Foods containing phytates have been reported to have beneficial impacts because they contain antioxidants that remove free radicals from the body (Olapade and Ogunade, 2014). The phytates can serve as prebiotics due to their capacity to bind enzymes such as amylases, causing a portion of the starch to enter the intestine undigested. Anti-nutrients may harm human health by limiting the digestibility and bioavailability of nutrients. However, the results from phytate content in extrudates are generally below the permissible limit of phytate in foods which is 250 to 500 mg/100g (Ndidi *et al*., 2014).

Oxalate content in the extruded ready-to-eat baby foods varied from 0.16 to 0.50 mg/100g and a significant (p<0.05) difference was observed among the samples.

The results are below the values (37.45 to 44.82

Table 5. Anti-nutrient composition (mg/100g) of Ready-To-Eat baby foods.

BP (Product)	ET	Phytate	Oxalate	Saponin
C0	70	1.79 ± 0.02^{a}	0.50 ± 0.00^{a}	0.35 ± 0.00^{d}
C1	70	1.51 ± 0.07^{b}	0.39 ± 0.01^{d}	0.48 ± 0.01^{a}
C2	70	1.10 ± 0.02^{d}	0.49 ± 0.03^{ab}	0.32 ± 0.00^{e}
C3	70	1.42 ± 0.05^{c}	0.45 ± 0.02^{bc}	0.37 ± 0.00^{c}
C4	70	1.47 ± 0.01^{bc}	0.41 ± 0.00^{cd}	0.39 ± 0.01^{b}
C0	90	0.96 ± 0.01^{e}	0.20 ± 0.01^{f}	0.21 ± 0.00^{h}
C1	90	0.47 ± 0.00^{g}	0.23 ± 0.01^{ef}	0.29 ± 0.01^{f}
C2	90	0.47 ± 0.01^{g}	0.26 ± 0.01^{e}	0.21 ± 0.00^{h}
C3	90	0.80 ± 0.01^{f}	0.16 ± 0.01^{g}	0.24 ± 0.00^{g}
C4	90	0.92 ± 0.01^{e}	0.20 ± 0.00^{f}	0.20 ± 0.00^{h}
BP (Composite Flour)				
C0		10.79 ± 0.03^{a}	1.45 ± 0.00^{e}	7.14 ± 0.01^{e}
C1		9.79 ± 0.01^{b}	2.32 ± 0.01^{b}	9.98 ± 0.01^{a}
C2		7.49 ± 0.02^{e}	3.10 ± 0.00^{a}	7.47 ± 0.01^{d}
C3		7.78 ± 0.03^{d}	2.12 ± 0.01^{c}	7.97 ± 0.01^{b}
C4		8.80 ± 0.01^{c}	1.71 ± 0.00^{d}	7.86 ± 0.01^{c}

Data are indicated in triplicate values as the mean ± standard deviation. Mean values with different superscript letters in the same column are significantly different ($p \leq 0.05$). Where BP is the blend proportions, ET: Extrusion temperature; C0 (control): 100:0:0; C1:50:25:25; C2:54.5:24:21.5; C3:50:30:20; and C4:54.5:26.5:19 for OFSP: Amaranth Seed: Soybean flour, respectively.

mg/100g) reported by Gemede (2020) for complementary foods formulated from maize, pea, and anchote flours, and the values (66.61±1.13, 83.18±3.99 and 77.13±2.61 mg/100g) reported by Abong *et al*. (2020) for bread from Kabode, SPK and Yellow sweet potato varieties in Kenya, respectively, but above to the range (0.11 to 0.17 mg/100g) reported by Awofadeju *et al*. (2021) for an extruded ready-to-eat breakfast snack. Oxalates can have harmful effects on human nutrition and health, such as reducing calcium absorption and aiding the creation of kidney stones. High intakes of soluble oxalate may cause calcium oxalate crystallization and the formation of kidney stones (nephrolithiasis) in the urinary tract (Irakli *et al*., 2021). Most urinary stones formed in humans are calcium oxalate stones; therefore, oxalate ingestion should not exceed 60 mg/day (Fategbe *et al*., 2021). The oxalate content of the extruded ready-to-eat baby foods is within the permissible limit which is between 0.3 to 0.5 mg/100g (Ndidi *et al*., 2014).

The saponin content of extruded ready-to-eat baby foods varied from 0.20 to 0.48 mg/100g. The results are below the range (35-73 mg/100g) reported by Fakolujo and Adelugba (2021) for extruded snacks made from acha, jack bean, and pawpaw flour blends and lower than the value 90 mg/100g reported by Airaodion *et al*. (2019) for traditional garri but in agreement with the results (0.0123-0.40 mg/100g) reported by Kowalski *et al*. (2016) for selected quinoa extrudates.

The majority of saponins are poisonous and bitter-tasting glycosidic chemicals made up of a steroid (C-27) or triterpenoid (C-30) nucleus with one or more carboxylate branches. The saponins are extremely heat-labile compounds and the concentrations of 3 to 7% are thought to be potent poisons, but concentrations of 1% are thought to be non-offensive; at 1.5 %, certain biological activity on injured mucous membranes have been observed (Aletor and Oreoluwa, 2019). There are a variety of edible and toxic saponins (steroid or triterpene glycoside molecules). Bitter saponins can prevent nutrients from being absorbed by blocking digestive and metabolic enzymes and reacting to nutrients like zinc. They are harmful at large doses. Saponins are organic substances that have numerous biological impacts (Awulachew, 2022).

Saponins can bind proteins, enhancing protein stability against heat denaturation and decreasing the susceptibility of proteins to proteases. They may also cause gastrointestinal lesions, entering into the bloodstream and hemolyzing the red blood cells (Bissinger *et al*., 2014). Saponins have properties of precipitating and coagulating red blood cells and they also exhibit hypocholesterolemic properties (cholesterol binding properties) by forming insoluble complexes with cholesterol, resulting in slower absorption, formation of foams in aqueous solutions, and hemolytic activity (Fategbe *et al*., 2021). The shear and thermal energy present likely are enough to destroy the original structure of the saponins, leading to the creation of smaller chemical fragments (Kowalski *et al*., 2016).

Extrusion cooking resulted in a significant reduction of phytate content, oxalate content, and saponin content of ready-to-eat baby foods and ranged from 81.71 to 95.23%, 65.24 to 92.63% and 95.06 to 97.43% reduction, respectively. The loss of these anti-nutrients during extrusion cooking might be attributed to the thermo-labile nature of these compounds. Similar observations were noted by many researchers. These anti-nutritional factors may be inactivated by processing methods involving heat generation (Ndidi *et al*., 2014). In plant foods, anti-nutritional factors are responsible for the deleterious effects of nutrient and micronutrient absorption. However, certain anti-nutrients may have beneficial health effects at low and medium levels, such as decreasing blood glucose

Table 6. Physical properties of extruded ready-to-eat baby foods

BP (Product)	ET (ºC)	Expansion ratio	Sectional expansion	Bulk density (g/cm^3)
C0	70	1.20±0.07^{ab}	1.45±0.17^{ab}	0.45 ±0.05^{a}
C1	70	0.93±0.09^{e}	0.88±0.19^{e}	0.30 ±0.04^{bc}
C2	70	1.05±0.10^{cd}	1.12±0.25^{cd}	0.36±0.06^{b}
C3	70	0.96±0.04^{de}	0.93±0.09^{de}	0.27 ±0.03^{c}
C4	70	1.02±0.04^{de}	1.05±0.09^{de}	0.34±0.08^{bc}
C0	90	1.24±0.13^{a}	1.56±0.33^{a}	0.43±0.07^{a}
C1	90	0.99±0.04^{de}	0.98±0.08^{de}	0.27±0.06^{c}
C2	90	1.14±0.07^{bc}	1.30±0.16^{bc}	0.35±0.04^{b}
C3	90	0.98±0.09^{de}	0.97±0.19^{de}	0.30±0.05^{bc}
C4	90	1.16±0.07^{ab}	1.35±0.17^{ab}	0.33±0.06^{bc}

Data are indicated in triplicate values as the mean ± standard deviation. Mean values with different superscript letters in the same column are significantly different ($p \leq 0.05$). Where BP is the blend proportions, ET: Extrusion temperature; C0 (control): 100:0:0; C1:50:25:25; C2:54.5:24:21.5; C3:50:30:20; and C4:54.5:26.5:19 for OFSP: Amaranth Seed: Soybean flour, respectively.

and insulin reactions to starchy foods and/or plasma cholesterol and triglycerides, reducing cancer risks due to their antioxidant effect (phytate, oxalate, saponin, etc) but in high concentration, they reduce the availability of nutrients and cause growth inhibition (Gemede and Ratta, 2014). In addition, the levels of phytate and oxalate in all extruded ready-to-eat baby foods fall within the safe permissible levels (0-5 %) for infant foods (Oche *et al*., 2017).

Expansion ratio and bulk density of ready-to-eat baby foods

The physical properties of ready-to-eat baby foods are shown in Table 6 and a significant difference ($p<0.05$) among samples was observed. The expansion ratio of extruded ready-to-eat baby foods ranged from 0.93 to 1.24 and a significant difference ($p<0.05$) was observed between the extrudates. The results are slightly below the range (2.941 to 3.559) reported by Naseer *et al*. (2021), for extrudate almond-pearl millet (APM) based snack but close to the trends (2.42 to 3.30) reported by Sahu and Patel (2020) for RTE extruded products and 2.0 to 2.6 reported by Omwamba and Mahungu (2014) for protein-rich ready-to-eat extruded snack from a composite blend of rice, sorghum, and soybean flour. In addition, the results confirm well the values (1.17±0.04 to 1.23±0.07) reported by Fang *et al*. (2019) for tuna meat-based extrudates. The sectional expansion ratio varied from 0.88-1.56 and falls within the range of 1.07 to 3.76 (mm^2 sectional area of the extrudate to sectional area of die), reported by Rweyemamu *et al*. (2015).

Expansion is a crucial physical characteristic of extruded food and consumers like extrudates with high expansion ratio and low bulk density owing to their puffiness. The expansion occurring in a food material depends on the pressure differential between the die and the atmosphere (Azeez *et al*., 2015). The expansion ratio was high in the control sample and low in the other samples. This may be an indication of the high carbohydrate and high protein content of extruded ready-to-eat baby foods. The extrudates expand more when there is more starch present, but they contract more when there is more protein.

The expansion ratio of the extrudates is an essential factor related to the interaction between starch and protein. The viscosity and elasticity of the dough, which are influenced by the ratio of starch, protein, and fibre, may have a role in the expansion (Nagaraju *et al*., 2021). In addition, the expansion ratio of extruded food products depends on the atmospheric pressure, water vapour pressure, and the ability of the product to sustain expansion (Liu *et al*., 2021). Increasing in rotating speed of the screw and barrel temperature results in high expansion and low expansion owing to the increase in moisture content (Shelar and Gaikwad, 2019).

Bulk density extruded ready-to-eat baby foods ranged from 0.27-0.45 g/cm^3 and a significant difference ($p<0.05$) was observed between the extrudates ($p<0.05$). The results are slightly above the range (0.107 to 0.156 g/cm^3) reported by Naseer *et al*. (2021), for extrudate almond-pearl millet (APM) based snack and 0.14 to 0.26 g/cm^3 reported by Sahu and Patel (2020) for RTE extruded products but within the values (0.41 to 0.59 g/cm^3) reported by Sobowale *et al*. (2021) for extruded snacks from whole pearl millet-based flour. The highest bulk density (0.45 g/cm^3) of extruded ready-to-eat baby foods was observed in the control sample which is OFSP only. This may be attributed to the highest carbohydrate content in OFSP. The higher the starch concentration, the greater the likelihood of a rise in bulk density. The high bulk density of flours implies that they are suitable for use in food preparation. Low bulk density, on the other hand, was found to be essential in complementary food formulations (Kaushik *et al*., 2021). The density of extruded food products is affected by the extrusion cooking conditions such as moisture content, temperature, and screw speed which is inverse to the expansion ratio (Shelar and Gaikwad, 2019).

Table 7. Sensory properties of extruded ready-to-eat baby foods.

BP	Appearance	Colour	Aroma	Taste	Texture	OA
C070	4.62 ± 0.49^{bc}	4.20 ± 0.40^{c}	4.00 ± 00^{e}	4.95 ± 0.21^{a}	4.51 ± 0.50^{b}	4.51 ± 0.50^{cd}
C170	4.94 ± 0.24^{a}	4.83 ± 0.38^{a}	4.49 ± 0.50^{bc}	4.92 ± 0.27^{a}	4.57 ± 0.50^{b}	4.91 ± 0.29^{a}
C270	4.52 ± 0.50^{c}	3.98 ± 0.60^{cde}	4.37 ± 0.49^{bcd}	4.42 ± 0.50^{bc}	4.40 ± 0.49^{bc}	4.68 ± 0.47^{bc}
C370	4.74 ± 0.59^{abc}	4.52 ± 0.50^{b}	4.77 ± 0.42^{a}	4.98 ± 0.12^{a}	4.37 ± 0.49^{bcd}	4.82 ± 0.39^{ab}
C470	4.62 ± 0.49^{bc}	4.17 ± 0.38^{cd}	4.40 ± 0.49^{bcd}	4.83 ± 0.38^{a}	4.45 ± 0.56^{bc}	4.80 ± 0.40^{bc}
C090	3.92 ± 0.27^{d}	3.55 ± 0.50^{f}	4.52 ± 0.50^{bc}	4.09 ± 0.29^{d}	4.23 ± 0.42^{cd}	4.03 ± 0.17^{g}
C190	4.77 ± 0.42^{ab}	3.97 ± 0.17^{de}	4.31 ± 0.47^{cd}	4.51 ± 0.50^{b}	4.57 ± 0.50^{b}	4.28 ± 0.45^{ef}
C290	4.00 ± 0.25^{d}	3.89 ± 0.31^{e}	4.60 ± 0.49^{ab}	4.08 ± 0.27^{d}	4.48 ± 0.50^{bc}	4.31 ± 0.47^{de}
C390	3.85 ± 0.36^{d}	3.23 ± 0.42^{g}	4.22 ± 0.41^{de}	4.23 ± 0.42^{cd}	4.14 ± 0.35^{d}	4.06 ± 0.24^{fg}
C490	4.74 ± 0.44^{abc}	4.00 ± 00^{cde}	4.17 ± 0.38^{de}	4.48 ± 0.56^{b}	4.89 ± 0.31^{a}	4.37 ± 0.49^{de}

Data are indicated as the mean ± standard deviation. Mean values with different superscript letters in the same column are significantly different ($p \leq 0.05$). Where C070-C470, are blend proportions extruded at 70°C while C090-C490, are blend proportions extruded at 90°C. C070 and C090 are acting as the control (Orange-fleshed sweet potato).

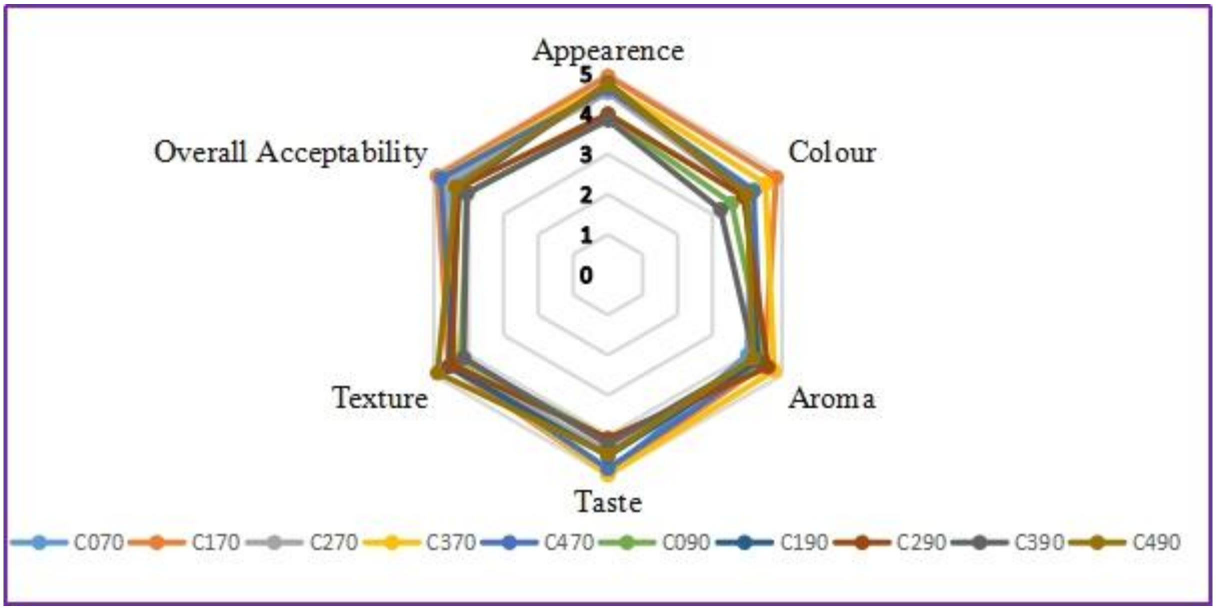


Figure 2. Radar graph representing sensory qualities of extruded ready-to-eat baby foods. OA: Overall acceptability, C070-C470, are blend proportions extruded at 70°C while C090-C490, are blend proportions extruded at 90°C.

Sensory characteristics of extruded ready-to-eat baby foods

Results from the sensory evaluation of extruded ready-to-eat baby foods are shown in Table 7 and a significant difference ($p<0.05$) was observed among the samples. This could be due to different ingredients used in formulations and also the composition of each extrudate. The sensory profile of all extruded ready-to-eat baby foods is graphically given in Figure 2. Among the 10 samples, the graph suggests that the samples with the best sensory scores in all the attributes are C170, C370 and C470 followed by C070, C490, C190, and C270, while the samples with the least favourable attribute are C290, C090, and C390. Taste was the attribute with the highest level of preference among the examined characteristics, followed by overall acceptability, appearance, and then texture, and aroma while colour had the lowest.

The appearance of extruded ready-to-eat baby foods which was the third attribute preferred by panellists ranged from 3.85 to 4.94. There was no significant difference ($p>0.05$) between samples C170, C370, C190, and C490 although C170 and C370 were the most preferred products among all tested extrudates. In addition, there was no significant difference ($p>0.05$) between samples C070, C370, C470, C190, and C490. The overall appearance of a product or package is frequently the crucial factor that influences the choice to purchase or consume a product. It includes the colour, size, shape, clarity, and surface texture of food products.

The colour of extruded ready-to-eat baby foods ranged from 3.23 to 4.83. There was no significant difference ($p>0.05$) observed between samples C070, C270, C470, and C490. Sample C170 scored more than other samples while C390 had the lowest score. Most samples extruded at 70°C scored higher than those extruded at 90°C in terms of colour even though there was no significant difference ($p>0.05$) between samples C270, C190, C290, and C490. The dark brown colour may be because extrusion cooking temperature and OFSP incorporation affected the colour of most food products.

The aroma of extrudates which was the fifth-ranked among attributes evaluated ranged from 4.00 to 4.77. There was no significant difference ($p>0.05$) observed between samples C170, C270, C470, C090, and C290. Furthermore, there was no significant difference ($p>0.05$) observed between samples C170, C270, C470, C090, and C190.

The taste of extrudates was the first attribute preferred by panellists and ranged from 4.08 to 4.98. There was no significant difference ($p>0.05$) observed between samples C070, C170, C370, and C470. In addition, samples C090, C290, and C390 revealed that there was no significant difference ($p>0.05$) observed between them in terms of taste. Taste (gustation) is properly defined as the reaction of the tongue to soluble, involatile substances (Kilcast, 2011). The texture which was the fourth attribute liked ranged from 4.14 to 4.89. There is no significant difference ($p>0.05$) observed between samples C070, C170, C270, C370, C470, C190, and C290. This could be because the panellists could not detect the difference among the extrudates regarding this sensory attribute. The sensation of touch detects texture, which is made up of two parts: somesthesis, a tactile surface reaction from the skin, and kinesthesis (or proprioception), a profound reaction from the tendons and muscles (Kilcast, 2011). The overall acceptability was the second attribute preferred by panellists and ranged from 4.03 to 4.91. There was no significant difference ($p>0.05$) observed between samples C070, C290, and C490. The acceptability of food products is crucial due to the distinct quality characteristics that attract consumers though there was no significant difference ($p>0.05$) observed between samples C270, C370, and C470. In addition, samples C190, C290, and C490 showed no significant difference ($p>0.05$) between them. On the other hand, the samples extruded at 70°C scored more than the ones processed at 90°C in terms of appearance, colour, taste, texture, and overall acceptability. This may be due to the brown colour of orange-fleshed sweet potato extrudates observed after extruding and drying of extrudates which were not preferred by most of the panellists. There was no significant difference ($p>0.05$) between the control sample (C070) and other samples in terms of appearance and overall acceptability while C090 was significantly ($p<0.05$) different from other products in terms of appearance, colour, taste, and overall acceptability.

Conclusion

Extrusion cooking temperature and blend proportions significantly ($p<0.05$) affect the nutritional quality, anti-nutrients, physical properties, and sensory properties of extruded ready-to-eat baby foods. The ingredients enhanced macronutrients and micronutrient contents of extruded ready-to-eat baby foods. The nutrient contents of the produced extruded ready-to-eat baby foods comply with the recommended standards based on the targeted nutrients studied in this study. The extruded ready-to-eat baby foods have reliable findings that can be used not only for stunted and wasted children below five years of age but also people who suffer from inadequate nutrient intake in developing countries. The anti-nutrient contents are at safe permissible levels for consumption. The extrusion cooking could be used in the production of high-quality extruded ready-to-eat baby foods with highly acceptable sensory qualities. The utilization of extruded ready-to-eat foods could help in achieving food and nutrition security as well as poverty reduction in developing countries if food products are standardized and marketed.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest

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