

Quality Assessment of Complementary Food Produced Using Fermentation and Roasting Methods

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Abstract This study aimed at assessing the quality of complementary food made from corn, millet and soybean using roasting and fermentation methods. There were two different compositions from each of the method. The functional properties, chemical composition, protein quality and sensory attributes of the formulated diets were determined and the results were analyzed using analysis of variance (ANOVA) and means were separated by Duncan multiple range tests. The difference between the control and the test diets was determined by t-test ($P < 0.05$). Results showed that there was significant difference in the water absorption and swelling capacity but the bulk density of the samples were not significantly different at $P < 0.05$. There was significant difference ($P < 0.05$) in the chemical composition of the test diets. The fermented complementary food had higher moisture content (7.2-8.2 %), crude fiber (14.0-19.8%), fat (12.3-12.6%) and protein (14.6-16.9%) while roasted samples was high in ash (2.3-3.2%), carbohydrate (50.0-52.8%) and energy (351.8-368.7%). The feed efficiency ratio of the control group was low (8.2) while the groups on roasted samples had higher feed conversion ratio (12.6 and 14.5). The PER of the test samples were comparable to PER for regular diet and the result of t-test showed that the regular diet was not significantly different from the test diets at $P < 0.05$. Furthermore, the results of sensory evaluation showed that there was no significant difference in the sensory quality of the test diets. The potential of roasted complementary food and fermented complementary food in meeting infant nutritional need was comparable.

Keywords: *complementary food, roasting, fermentation, infant feeding, protein quality*

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1. Introduction

Adequate nutrition during infancy and early childhood is fundamental to the development of each child's full human potential. It is well recognized that the period from birth to two years of age is a "critical window" for the promotion of optimal growth, health and behavioral development. Longitudinal studies have consistently shown that this is the peak age for growth faltering, deficiencies of certain micronutrients, and common childhood illnesses such as diarrhea [1]. Studies have also shown that breast milk is the ideal food for infants during the first six months of life. However, breast milk alone cannot provide all the nutrients and calories that allow infants to thrive or increase in birth weight after six months of life. Therefore infants and young children from six months until two years are gradually introduced to different types of nutritious semi-solid or complementary foods [2].

Complementary feeding is defined as the process starting when breast milk alone is no longer sufficient to meet the nutritional requirements of infants, and therefore other foods and liquids are needed, along with breast milk. The target age range for complementary feeding is generally taken to be 6 to 24 months of age, even though breastfeeding may continue beyond two years [3]. To

ensure adequate energy and nutrient, an infant's diet must be gradually expanded to include complementary foods, these foods complement breast milk, not replace it. Complementary foods when introduced too early or too frequently displace breast milk.

Regardless of the degree of processing, complementary foods should have specific attributes that encourages their use in infant feeding. Nutritional scientists consider the innate biological properties of food as valuable, specifically complementary foods should contain sufficient energy, micronutrients and should be safe for consumption. Processed complementary foods should have certain characteristics such as; appropriate viscosity for age because children need semi-solid preparation until about 12 months of age, desirable sensory properties, processed (if necessary to avoid the presence of anti-nutritional factors), easy to prepare without making excessive demands on care givers, low cost and fun to eat [2].

Commercially available complementary foods are not within the reach of low income families as a result most families depend on local staple foods. Household technologies such as fermentation, soaking, roasting and malting can contribute to improved safety and quality of complementary foods. Roasting method is used for production of tom brown and fermentation method for production of ogi (pap). Tom brown is in dried form while ogi is wet and this could make storage of tom brown

more convenient. However, research has shown that fermentation increase nutritional composition of food [4]. Reaching an adequate nutrient level remains a concern, particularly in diets that are mainly plant-based [5]. There have been different approaches to increase nutritional content of complementary foods. Some research varied blends of starchy staples with different legumes while different processing methods are also being studied. Research is still being intensified in this area as the problem of malnutrition in children is still a challenge in Africa. Thus, this work compared the functional, nutritional, and sensory qualities of complementary food produced using roasting and fermentation methods respectively.

2. Materials and Methods

2.1. Materials

The food commodities; corn (*Zea mays*), millet (*Pennisetum glaucum*), soybean (*Glycine max*) used in making the complementary food were purchased from an open market in Ogun State, Nigeria.

2.2. Fermentation Method

Corn, millet and soybean were picked; washed, dried, hammer milled into flour (0.7mm mesh screen) and packaged in polyethylene bag. The different combinations of the flour were put in containers with water (ratio of 1:3 w/v) separately and subjected to rapid fermentation at $28 \pm 2^\circ\text{C}$ for 24 h. The water used for fermentation was made up of one-third of steep water from previously fermented corn. The fermented samples were dried at 60°C in an air oven, hammer milled into fine flour (0.5 mm mesh screen) and stored in tightly covered containers until they were required for analysis and production of gruels [6]. Figure 1 shows the production of the complementary food using fermentation method.

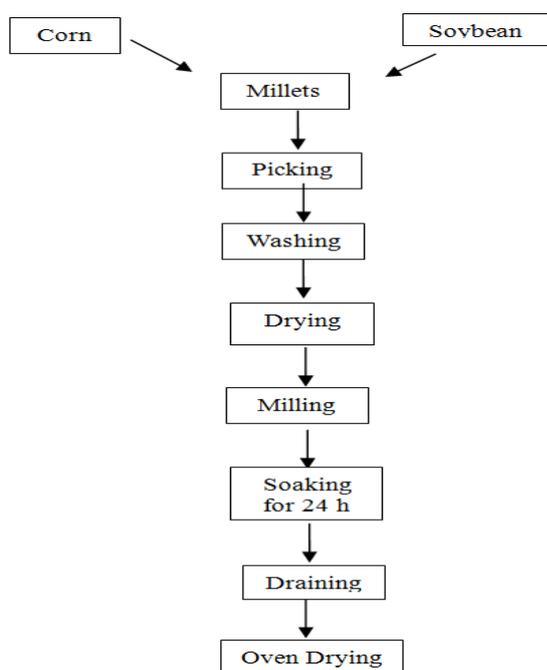


Figure 1. Fermentation method for corn, millet and soybean

2.3. Roasting of Corn and Millets

The millets was washed by pouring into a big bowl filled with water with continuous stirring before draining. The process was repeated severally until the water was clear and the stones were all removed. The corn and millets were dried and roasted at 170°C in an air oven with continuous stirring. There was frequent checking to prevent burning and was removed after a dark brownish colour was obtained [7]. This is as shown in Figure 2.

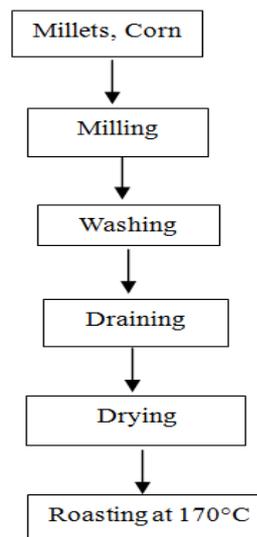


Figure 2. Roasting method for corn and millet

2.4. Roasting of Soybean

The dirt in the soybeans was removed and the soybean was soaked in water for 20 min. After which the soybean seeds was dehulled and dried to a constant weight. The dried seeds were roasted at temperature of 170°C for 30 min with continuous stirring until a characteristic slightly brown colouration was obtained. The seeds were allowed to cool and then ground into fine powder (Figure 3). The ground soybean was sieved using a 1 mm pore sieve [7].

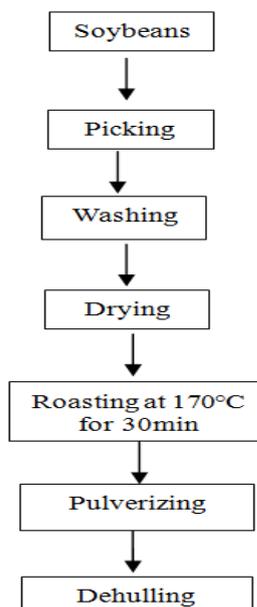


Figure 3. Roasting method for soybean

2.5. Formulation of Composites

The prepared samples from fermentation and roasting methods were milled separately into flour using hammer mill.

Table 1. FORMULATION OF THE COMPOSITES

	Fermentation method		Roasting method	
	Test Diet 1	Test Diet 2	Test Diet 3	Test Diet 4
Millet	40%	30%	40%	30%
Soybean	30%	30%	30%	30%
Corn	30%	40%	30%	40%

2.6. Water Swelling Capacity

The swelling capacity was determined by the method described by Okaka and Potter [8]. 100 ml graduated cylinder was filled with the sample to 10 ml mark. The distilled water was added to give a total volume of 50 ml. The top of the graduated cylinder was tightly covered and mixed by inverting the cylinder. The suspension was inverted again after 2 min and left to stand for a further 8 min and the volume occupied by the sample was taken after the eighth minute.

2.7. Water Absorption Capacity

One gram of sample mixed with 10 mL distilled water was allowed to stand at ambient temperature ($30 \pm 2^\circ\text{C}$) for 30 min and centrifuged for 30 min at 3000 rpm or $2000 \times g$. Water absorption was expressed as grams of water absorbed by 1 g of the flour sample [9].

2.8. Bulk Density

This was determined using the method described by Onwuka [10]. About 2.5 g of sample was filled in a 10 ml graduated cylinder and its bottom tapped on the laboratory bench until there was no decrease in volume of the sample. The volume of sample in the cylinder was recorded.

$$\text{Bulk density} = \frac{\text{Wt. of sample (g)}}{\text{Vol. of sample (ml)}}$$

2.9. Moisture Content

Moisture content was determined using Association of Official Analytical Chemist [11] method. About 5 g of sample was weighed into Petri dish of known weight. It was then dried in the oven at $105 \pm 1^\circ\text{C}$ for 4 h. Then the samples were cooled in a desiccator and weighed. The moisture content was calculated as follows:

$$\text{Percentage moisture content} = \frac{\text{Change in weight}}{\text{Initial weight of food before drying}} \times 100.$$

2.10. Protein Content

The protein content was determined using a micro- Kjeldhal method [11] which involves wet digestion, distillation,

and titration. The protein content was determined by weighing 3 g of sample into a boiling tube that contained 25 ml concentrated sulphuric acid and one catalyst tablet containing 5 g K_2SO_4 , 0.15 g CuSO_4 and 0.15 g TiO_2 . Tubes were heated at low temperature for digestion to occur. The digest was diluted with 100 ml distilled water, 10 ml of 40% NaOH, and 5 ml $\text{Na}_2\text{S}_2\text{O}_3$, anti-bumping agent was added, and then the sample was diluted with 10 ml of boric acid. The NH_4 content in the distillate was determined by titrating with 0.1 N standards HCl using a 25 ml burette. A blank was prepared without the sample. The protein value obtained was multiplied by a conversion factor, and the result was expressed as the amount of crude protein.

% crude protein

$$= \frac{\left[\frac{(\text{Actual titre value} - \text{Titre of the blank})}{\text{x0.1N HCl x 0.014 x conversion factor}} \right]}{\text{weight of the sample}} \times 100$$

2.11. Fat Content

Fat content was determined using the method of AOAC [11]. About 10 g of sample wrapped in a filter paper was weighed using a chemical balance. It was then placed in an extraction thimble that was previously cleaned, dried in an oven, and cooled in the desiccator before weighing.

Then, about 25 ml of petroleum ether solvent was measured into the flask and the fat content was extracted. After extraction, the solvent was evaporated by drying in the oven. The flask and its contents were cooled in a desiccator and weighed.

The percentage fat content was calculated as follows:

$$\text{\% of total fat content} = \frac{\text{Weight of extracted fat}}{\text{Weight of food sample}} \times 100.$$

2.12. Ash Content

About 5 g of each sample was weighed into crucibles in duplicate, and then the sample was incinerated in a muffle furnace at 550°C until a light grey ash was observed and a constant weight obtained. The sample was cooled in the desiccators to avoid absorption of moisture and weighed to obtain ash content [11].

2.13. Crude Fibre

About 5 g of each sample was weighed into a 500 ml Erlenmeyer flask and 100 ml of TCA digestion reagent was added. It was then brought to boiling and refluxed for exactly 40 minutes counting from when it started boiling. The flask was removed from the heater, cooled a little then filtered through a 15.0 cm no. 4 whatman paper. The residue was washed with hot water stirred once with a spatula and transferred to a porcelain dish. The sample was dried overnight at 105°C . After drying, it was transferred to desiccators and weighed as W1. It was then burnt in a muffle furnace at 500°C for 6 h, allowed to cool, and reweighed as W2 (11).

$$\text{Percentage crude fibre} = \frac{W1 - W2}{W0} \times 100$$

W1=weight of crucible + fibre + ash

W2=weight of crucible + ash

W0=Dry weight of food sample.

2.14. Total Carbohydrate Content

Carbohydrate content was determined by difference using the method of Egounlety and Awoh [12], by subtracting the total sum of the percentage of fat, moisture, ash, crude fibre, and protein content from one hundred (100).

2.15. Energy Content

Energy content was determined according to Atwater and Woods [13]. The system is based on the heats combustion of protein, fat and carbohydrate, which are corrected for losses in digestion, absorption and urinary excretion of urea. It uses a single factor for each of the energy-yielding substrates (protein, fats and carbohydrates), regardless of the food in which it is found. The energy values are 17kJ/g (4.0 kcal/g) for protein, 37kJ/g (9.0kcal/g) for fat and 17kJ/g (4.0 kcal/g) for carbohydrate.

2.16. Protein Digestibility

Experimental rats and management: Twenty-five weanling albino rats (3-4 weeks old) of the wistar strain was obtained from the Babcock University Animal Laboratory. They were randomly selected and distributed into five groups of five rats per group (a group being the control) and were kept in metabolic cages. There was a preliminary period of fourteen [14] days during which the animals were fed regular rat pellet. After this preliminary period, the rats were fed experimental diets. A group was fed test diet1 which was 40% millet, 30% soybean, 30% corn and another group was fed test diet 2 (30% millet, 30% soybean and 40% corn) both from fermentation method. The third group was fed test diet 3 which was 40% millet, 30% soybean, 30% corn and the fourth group was fed with test diet 4 which was 30% millet, 30% soybean and 40% corn both from roasting method. The control group was fed regular rat pellet which contained 20 % protein, 0.41% calcium, 0.45% available phosphorus, 0.5% fiber, 3.68% fat and oil with 2648 kcal of energy. The experiment lasted for 3 weeks (21) days. Data was collected on the following and analyzed.

2.17. Feed Intake (g)

Feed was given twice daily to the rats in each treatment, in the morning and evening and the feed residues was collected and weighed after drying in the oven at 80 °C for 48 h [14].

2.18. Body Weight Changes (g)

Initial live weights of the rats were taken after the preliminary period at the beginning of the experiment and weekly throughout the 4 weeks period of the study. The

weight gained was obtained by subtracting the initial weight from the final weights [14].

2.19. Feed Conversion Ratio

Feed conversion ratio was calculated as feed intake (g) per weight gained.

$$\text{FRC} = \frac{\text{feed intake (g)}}{\text{Weight gained}} \quad [14]$$

2.20. Protein Efficiency Ratio (PER)

PER was calculated using; $\frac{\text{Weight gained (g)}}{\text{Protein intake (g)}}$. [15]

2.21. Sensory Evaluation

Sensory evaluation was conducted on the reconstituted samples and ten panelists comprising of female students in Babcock University participated in the study instead of the target recipient (children) because of their supposed ability to objectively evaluate the sensory characteristics of the formulation [2].

The attributes that were assessed are colour, texture, taste, aroma and general acceptability. The hedonic scale ratings are; 1=dislike extremely, 2=dislike very much, 3=dislike moderately, 4=dislike slightly, 5=neither like nor dislike, 6=like slightly, 7=like moderately, 8=like very much, 9=like extremely.

2.22. Statistical Analysis

One way analysis of variance (ANOVA) and Duncan Multiple Range Tests were used to determine the significant difference and to separate means of the functional properties, chemical composition and sensory attributes. The feed intake, body weight change, FCR and PER were analysed using t-test at $p \leq 0.05$ using Statistical Package for Social Sciences (SPSS) version 20.0.

3. Results

3.1. Functional Properties

Results of the functional properties complementary food produced by roasting and fermentation is as presented in Table 2. There was significant difference in the water absorption which ranged between 1.0- 2.0 g and water swelling capacity (1.5 – 7.0 ml). The bulk density was between 0.6 – 0.7 g/ml and was not significantly different for all the samples.

3.2. Chemical Composition

The chemical composition of the samples was significantly different (Table 3). The moisture content ranged between 5.4 – 8.2 %, Ash (1.7- 3.2 %), fat (9.8 – 12.6 %), fibre (14.0 – 19.8 %), protein (13.1 – 16.9%), carbohydrate (44.4 – 52.8 %) and energy (346.7 – 368.7 %).

Table 2. Functional properties of the complementary diets

Functional properties	Test diets			
	Test diet 1	Test diet 2	Test diet 3	Test diet 4
Water absorption (g)	1.0 ^c	1.5 ^b	1.5 ^b	2.0 ^a
Water swelling (ml)	7.0 ^a	6.0 ^a	2.0 ^b	1.5 ^b
Bulk density (g/ml)	0.6 ^a	0.6 ^a	0.6 ^a	0.7 ^a

Means with the same superscript along the rows are not significantly different ($P < 0.05$)

Test diet 1: 40% millet, 30% soybean and 30% corn from fermentation method

Test diet 2: 30% millet, 30% soybean and 40% corn from fermentation method

Test diet 3: 40% millet, 30% soybean and 30% corn from roasting method

Test diet 4: 30% millet, 30% soybean and 40% corn from roasting method.

Table 3. Chemical composition of the complementary diets

Chemical Components	TEST DIETS			
	Test diet 1	Test diet 2	Test diet 3	Test diet 4
Moisture (%)	8.2 ^a	7.2 ^b	5.4 ^c	5.7 ^c
Ash (%)	2.0 ^{bc}	1.7 ^c	3.2 ^a	2.3 ^b
Fat (%)	12.6 ^a	12.3 ^a	9.8 ^a	11.5 ^b
Fiber (%)	14.0 ^c	19.8 ^a	15.7 ^b	14.2 ^c
Protein (%)	16.9 ^a	14.6 ^c	13.1 ^c	16.3 ^b
Carbohydrate (%)	46.4 ^c	44.4 ^a	52.8 ^a	50.0 ^b
Energy (Kcal)	366.2 ^a	346.7 ^c	351.8 ^b	368.7 ^a

Means with the same superscript along the rows are not significantly different ($P < 0.05$)

Test diet 1: 40% millet, 30% soybean and 30% corn from fermentation method

Test diet 2: 30% millet, 30% soybean and 40% corn from fermentation method

Test diet 3: 40% millet, 30% soybean and 30% corn from roasting method

Test diet 4: 30% millet, 30% soybean and 40% corn from roasting method.

Table 4. Protein quality of the complementary diets

Samples	Protein quality					Regular diet compared with the test diets	
	Mean feed consumed (g)	Mean protein consumed (g)	Mean weight gained (g)	FCR	PER	T	Sig. (2 tailed)
Regular diet (control)	369.6	73.9	45.0	8.2	0.6		
Test diet 1	237.0	39.5	20.7	11.4	0.5	1.519	.203
Test diet 2	322.8	47.2	31.8	10.2	0.6	1.867	.135
Test diet 3	347.2	45.6	27.6	12.6	0.6	1.998	.116
Test diet 4	257.4	41.9	17.7	14.5	0.4	1.566	.192

Level of significance is at $P < 0.05$

Test diet 1: 40% millet, 30% soybean and 30% corn from fermentation method

Test diet 2: 30% millet, 30% soybean and 40% corn from fermentation method

Test diet 3: 40% millet, 30% soybean and 30% corn from roasting method

Test diet 4: 30% millet, 30% soybean and 40% corn from roasting method

Table 5. Sensory quality of the complementary diets

Parameters	TEST DIETS			
	Test diet 1	Test diet 2	Test diet 3	Test diet 4
Colour	7.1 ^a ±1.66	7.0 ^a ±2.05	7.2 ^a ±1.32	8.0 ^a ±0.82
Odour	5.9 ^b ±1.66	6.3 ^{ab} ±2.83	7.5 ^{ab} ±1.08	7.9 ^a ±0.74
Viscosity	6.7 ^a ±1.57	6.5 ^a ±1.84	6.1 ^a ±1.37	6.2 ^a ±2.20
Taste	5.2 ^a ±2.04	5.3 ^a ±2.58	6.1 ^a ±2.18	6.0 ^a ±2.83
Acceptability	6.2 ^a ±2.30	6.1 ^a ±2.18	6.9 ^a ±1.29	7.4 ^a ±1.35

Means with the same superscript along the roles are not significantly different ($P < 0.05$)

Test diet 1: 40% millet, 30% soybean and 30% corn from fermentation method

Test diet 2: 30% millet, 30% soybean and 40% corn from fermentation method

Test diet 3: 40% millet, 30% soybean and 30% corn from roasting method

Test diet 4: 30% millet, 30% soybean and 40% corn from roasting method.

3.3. Protein Quality

The mean feed consumed by the rats on test diet 4 was the lowest (257.4g) while the control on the regular diet had mean feed consumed of 369.6 g. Mean protein consumed by the rats on the test diet 1 was the least (39.5 g) while the rats on regular diet (control) consumed highest amount of protein (73.9 g). Mean weight gain of the control group (45.0 g) was higher than the test groups. However, it had the lowest feed conversion ratio (FCR) of 8.2. The protein efficiency ratio (PER) of control and the test groups was between 0.4 and 0.6. This is as presented on [Table 4](#).

3.4. Sensory Qualities

The samples were only significantly different in odour ([Table 5](#)). The mean values for colour ranged between

7.0 and 8.0, viscosity (6.1- 6.7), taste (5.2 – 6.1) and acceptability (6.1 – 7.4).

4. Discussion

4.1. Functional Properties

Combination of different food products to produce complementary food that will adequately meet the nutritional needs of babies has been of great interest in the developing countries. As a contribution towards this effort, complementary food was formulated with corn, millet and soybean and were processed by roasting and fermentation methods to determine the method that gives the most nutritious food. The functional properties of the different test diets were determined ([Table 2](#)). The water absorption

recorded was 1.25 – 4.71, swelling capacity was 1.4 – 2.71 and bulk density 0.46 – 0.50 for the test diets. There was significant difference in the water absorption (with roasted samples having better absorption property) and swelling capacity but the bulk density of the samples was not significantly different at $P < 0.05$. The functional properties though with some variations are comparable to earlier reports of Ogunka-Nwoka and Mepha [16] and Afam- anene and Ahiaarakwem, [2] for formulated complementary food and nutrend, a commercial complementary food. Only the swelling capacity of the fermented test diets was higher than what was reported in some of the previous findings. However, high swelling capacity of the fermented complementary food is not desirable as this may reduce the nutrient density of the food and high water absorption of roasted samples is also disadvantageous as it limits the absorption of nutrients by the infant [2].

4.2. Chemical Composition

There was significant difference ($P < 0.05$) in the chemical composition of the test diets (Table 3). The fermented complementary food had higher moisture content, crude fiber, fat and protein while roasted samples were high in ash, carbohydrate and energy. The moisture content of 5.4 to 8.2%, protein; 13.1 to 16.9 % and ash 1.7 to 3.2 % of the test diets are comparable to what was reported by Akinola et al. [17] and Afam- anene and Ahiaarakwem [2] for formulated complementary food and nutrend. However, the test diets were higher in fat content and crude fiber but lower in total carbohydrate and energy when compared with these earlier findings. It was observed during processing of fermented test diets that in removing the steep water some food particles were removed along with it as it was not easy separating the steep water from the mash. There was every possibility of some nutrients like protein, carbohydrate, vitamins and minerals being lost in the steep water.

4.3. Protein Quality

In determining protein quality (Table 4), animals on test diet 1 (40% millet, 30% soybean and 30% corn from fermentation method) and test diet 4 (30% millet, 30% soybean and 40% corn from roasting method) were found to consumed less food, thus protein intake of these groups was low and their mean weight gain was also lower than that of the other two groups. The regular feed contain more protein and the animals in the control group consumed more protein (mean protein consumed being 73.9) than the test groups which reflected in their weight gain (45g). However, the feed efficiency ratio was low (8.2) while the groups on test diet 3 (40% millet, 30% soybean and 30% corn from roasting method) and test diet 4 (30% millet, 30% soybean and 40% corn from roasting method) which were roasted samples had higher feed conversion ratio (12.6 and 14.5). The protein efficiency ratio (PER) of the fermented samples (test diet 1 and 2) were 0.6 and 0.5 and that of the roasted samples were 0.6 and 0.4 for test diet 3 and 4 respectively. These PER of the test samples are comparable to PER for regular diet and the result of t-test showed that the regular diets was not significantly different from the test diets at $P < 0.05$. The

PER of the test samples (except test diet 4) are higher than 0.42 and 0.47 reported by Adejo-ogiri and Adepoju [18] for complementary food supplemented with *Cirina forda*.

4.4. Sensory Quality

The results of sensory evaluation (Table 5) showed that there was no significant difference in the colour, taste, viscosity and acceptability though the roasted samples were rated higher in colour, taste and acceptability while fermented samples were better rated for viscosity. The samples were significantly different in odour, with the roasted samples being significantly different from the fermented samples which could be attributed to development of odour during fermentation. Thus, generally the panelists rated roasted samples better than the fermented samples in all the sensory parameters investigated except for viscosity.

5. Conclusion

Complementary food produced by fermentation had high swelling capacity which may affect the nutrient density of the food whereas roasting produced food with high water absorption which is also detrimental to the absorption of nutrient by the infants. Complementary food produced by fermentation had higher content of protein, fat and crude fiber while roasting produced complementary food high in carbohydrate and energy. The feed conversion ratio of roasted food was higher, while the two methods produced complementary food with comparable protein efficiency ratio. The complementary food produced by the two methods was generally acceptable.

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