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Research Paper

Effects of fermentation time on the functional properties of *ogiri-ahuekere (Arachis hypogaea* Linn) seed condiment

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Abstract. The effects of fermentation time on the functional characteristics of *ogiri-ahuekere* samples were evaluated. The groundnut seeds were sun-dried for 8 hours, dehulled and boiled for 8 hours using kerosene stove. The cooked cotyledons were milled manually into a paste and wrapped in small portions (30 g) with blanched plantain leaves. The wrapped samples were fermented in a container for 1 to 10 day(s) while the unfermented cooked groundnut paste was used as a control. Statistical analyses of the data were carried out using ANOVA method with the application of SPSS Version 20. The significant difference between the mean values was determined by Tukey's test at 95% level of confidence. Increase in fermentation time caused significant decrease in the following functional properties of *ogiri-ahuekere* such as water absorption capacity (99.72 to 49.51%), foaming stability (60.63 to 31.60%), and swelling index (4.00 to 0.78), whereas the increase in fermentation time caused significant increase in the following functional properties: oil absorption capacity (72.70 to 128. 43%), foaming capacity (1.37 to 6.84), emulsifying capacity (40.87 to 97.47%), bulk density (0.13 to 0.75 gm^{-3}) and gelling point (62.33 to 88.33˚C). This showed that increase in the fermentation time improved the functional properties of the *ogiri-ahuekere* samples.

Keywords: Condiment, *ogiri*, groundnut, fermentation, functional properties.

INTRODUCTION

Condiments are edible substances which are added to impart a particular flavour, enhance its flavour, and in some cultures to complement the dish. Many condiments are packaged in single-sachets/packets e.g. mustard and ketchup. They are prepared from both plant and animal materials using processes in which micro-organisms play active roles in the physical, nutritional and sensory modification of the starting materials. The local condiment is an oily paste with strong putrid ammonical odour made from fermented vegetable protein (Achi, 2005; Chukwu *et al.*, 2017; 2018a, b). Condiments are prepared by traditional methods of uncontrolled solid substrate fermentation resulting in extensive hydrolysis of the protein and carbohydrate components. Traditional condiments are used as soup condiments and they generally have strong aroma. Condiments are excellent sources of proteins with essential amino acids, and also contain lipids, carbohydrates, essential fatty acids and vitamins (Ouoba *et al*., 2003a, b). Many families in West Africa often used fermented condiments as low cost meat substitute. Fermented condiments improve nutritive values of foods as well as sensory properties as taste enhancers; contain antioxidants and nutraceuticals that promote health (Yagoub *et al*., 2004).

Fermented condiments often have a stigma attached to them as they are considered to be food for the poor (Arogba *et al*., 1995). Traditional diets in Nigeria often lack variety and consist of large quantities of the staple

foods (cassava, yam, maize) with supplements of plantain, cocoyam, rice and beans depending on their availability and seasons (Achi, 1999). Soups eaten with the staples are essential components of the diet and may contain a variety of seeds, nuts, pulses and leaves (Cambell-Platt, 1987; Chukwu *et al*., 2017, 2018a, b).

Fermentation is one of the oldest and most economical methods of producing and preserving foods in developing countries (Achi, 2005). Fermentation remains of interest since they do not require refrigeration during distribution and storage (David and Aderibigbe, 2010). Apart from increasing the shelf life, and a reduction in the anti-nutritional factors, fermentation markedly improves the digestibility, nutritive value and flavour of the raw seeds (Barimalaa *et al*., 1989; Achi and Okereke, 1999; Chukwu *et al*., 2017, 2018a, b). Fermented foods are essential part of diets for the world particularly in Africa. Cereals, legumes and oil seeds are used in production of fermented foods. Seeds of legumes may account for up to 80% of dietary protein and may be the source of protein for some low income earners. Their cooked forms are eaten as condiments to enhance the flavours of foods. With high content of protein, legume condiments can serve as tasty meals or complement of sauces and soups, and can substitute for fish or meat (Achi, 1992).

Ogiri generally refers to as oily paste made from oil seeds in West Africa. They are also used as soup condiments with strong smell. It is a product of fermentation of melon seeds (*Citrullus vulgaris*). *Ogiri egusi* is a food flavouring condiments prepared by traditional methods of uncontrolled solids state fermentation of melon seeds involving the use of chance fermentation (Akinyele and Oloruntoba, 2013). Proteinous oil seeds like castor oil seeds (*Ricinus communis*), melon seeds (*Citrullus vulgaris*) and fluted pumpkin seeds (*Telferia occidentalis*) apart from serving as sources of fats and oils, have been processed by cooking and microbial fermentation into a local food seasoning called *ogiri* (Nzelu, 2006). It is usually employed in small proportion in food/soup preparations but indispensible. It does not only enrich the soups with proteinous meaty taste, it also gives some health benefits (Nzelu, 2006).

Groundnut is an important oil crop of Brazilian origin, is cultivated in tropical and warm temperate climates. It is specie in the legumes or “bean” family (*Fabaceae*). It is also widely produced in Guinea Savannah ecological zone of Nigeria. It is cultivated in tropical and warm temperate climate (Richard, 1997). Groundnuts grow best in light, sandy loam soil. The crop is grown usually as a component of a variety of crop mixtures including sorghum, millet, cowpea and maize. Groundnut is an important oil seed and cash crop accounting for more than one-third of the total oil seeds in the world (Sahayuraj and Martin, 2003). *Arachis hypogaea*, commonly referred to as groundnut, is known in India as *cheenabadam*, in Ghana as *dagomba* and in Nigeria as *ahuekere (Ibo)*, *jada (Hausa)* (Musa *et al*., 2010).

Groundnuts are not only rich in proteins which are easily digestible and consequently, a higher biological value, but also rich in B-complex vitamins. It is an important item in several confectionery products and formulations in combination with cereals and pulses in developing countries. The vast food preparations incorporating groundnut to improve the protein level has helped in no small way in reducing malnutrition in developing countries (Pillari *et al*., 1984).

Functional properties have been defined as those characteristics that govern the behavior of nutrients in food during processing, storage and preparation as they affect food quality and acceptability. Similarly, functionality is defined as any property of a food or food ingredient, besides the nutritional ones that affects its utilization. Research in the nutritional and functional properties of oil seeds, particularly legumes, has resulted in their extensive utilization in processed foods such as sausage-type meats and marshmallows, whipped toppings, and bakery products. Solubility of proteins under varying conditions is one of its important functional properties, because this greatly influences other properties such as emulsification, foaming and gelation; thus, the protein may possess satisfactory properties e.g., nutritional value, acceptable flavor, and texture (Onwuka, 2005, 2018). Functional properties of food protein are important in food processing and product formation. Some of these properties are water absorption capacity, oil absorption capacity, emulsion capacity, foam capacity, whippability, viscosity, swelling capacity, pH, bulk density, wettability, gelation capacity, gelatinization point etc. (Onwuka, 2005, 2018).

Lack of adequate food preservation technology is a major problem contributing to food insecurity in Nigeria. The high cost and infrastructural requirement of many advanced food preservation methods such as canning, freezing, refrigeration and irradiation have reduced their applications in the developing countries. This implies that promoting fermentation technology in Nigeria is helping to promote food security (Enujiugha, 2000; Enujiugha and Agbaede, 2000). Most commercial seasonings including magi are expensive due to the high cost of raw materials used for their preparation. While castor seeds and melon seeds are also costly, the fluted pumpkin seeds are very scarce and in short supply (Umeh *et al*., 2013).

The main objective of this work is to produce *ogiri-ahuekere* by fermentation of groundnut seeds using traditional method and to determine effect of fermentation time on the functional properties of the fermented *ogiri-ahuekere* condiment samples.

MATERIALS AND METHODS

Source of materials

The groundnuts seeds were bought from a local market at Aba, Abia State, Nigeria. The reagents used were of analytical grade. Reagents were produced by BDH

Chemicals Ltd, Poole England.

Production of *ogiri* samples

Five hundred grams (500 g) groundnut seeds were weighed and spread under the sun for 8 h easy removal of the seed coats (hulls). The hulls were removed by rubbing the seeds in-between the palms (Wakshama *et al*., 2009, 2010; Chukwu *et al*., 2017, 2018a, b).

Preparation of *ogiri* from dehulled groundnut seeds

The cotyledons were boiled at 100°C for eight (8) hours using kerosene stove. After which the water was drained–off and allowed to cool. The cooked cotyledons were milled into a paste manually using pestle and mortar. The paste was wrapped in small portions of approximately 30 g with blanched plantain leaves and left to ferment in a container for 1 to 10 day(s) (Omafuvbe *et al*., 2003a, b). The unfermented sample served as control and the other ten samples were known as *ogiri-ahuekere* (fermented groundnut condiment). Both the fermented condiment and unfermented condiment were used for analyses. Figure 1 shows the flow diagram for the production of *ogiri-ahuekere* (Chukwu *et al*., 2017).

Analysis of the functional properties of *ogiri-ahuekere* samples

Dried eleven fermented *ogiri-ahuekere* samples were used for this analysis.

Determination of water absorption capacity

The method of Sosulski (1962) was described by Abbey and Ibeh (1988) and it was adopted. One gram (1 g) of each sample was weighed out into a dry, clean centrifugal tube and both weight noted. 10 ml of distilled water was poured into the tube containing each sample and properly mixed with the sample to make a suspension. It was then centrifuged at speed of 3500 rpm for 15 mm. After which supernatant was discarded then the tube and its content re-weighed and noted. The gain in weight is the water absorption capacity of the test sample (Ibeabuchi, 2014). The water absorption capacity of the test sample was repeated three times for each sample and the average was calculated.

$$\%WAC = \frac{weight\ gain}{weight\ of\ sample} \times 100 \quad (1)$$

Determination of oil absorption capacity

The method of Sosulski (1962) as described by Abbey and Ibeh (1988) was adopted. One gram of each sample was weighed into a dry, clean centrifugal tube and both weight noted. 10 ml of refined vegetable oil was poured into the tube and properly mixed with the flour. The suspension was centrifuged at 3500 rpm speed for 15 min, then the supernatant was discarded, the tube with its content re-weighed. The gain in mass is the oil absorption capacity of the sample (Ogunbusola *et al*., 2012). The oil absorption capacity of the test sample was repeated three times for each sample and the average was calculated.

$$OAC = \frac{weight\ gain}{weight\ of\ sample} \times 100 \quad (2)$$

Determination of foam capacity and stability

The method as described by Onwuka (2005, 2018) was adopted in the determination of foam capacity. One gram of the *ogiri* was whipped into 100 ml distilled water and its volume noted. The suspension was blended with a warming blender 1600rpm for 5min. It was then poured into a 250 ml measuring cylinder, its volume noted and recorded. Using Abbey and Ibeh (1988) formula, foam capacity is expressed percentage increase in volume is as follows:

$$\text{Foam capacity} = \frac{\text{Volume after whipping} - \text{volume before whipping}}{\text{Volume before whipping}} \quad (3)$$

The volume of foam capacity and the volume of the foam after 60 min were used to determine the stability for the whipping as described by Chinma *et al*. (2008). The foam capacity and stability of the test sample was repeated three times for each sample and the average was calculated.

$$\text{Foam stability} = \frac{foam\ volume\ after\ 60minutes}{initial\ foam\ volume} \times 100 \quad (4)$$

Determination of emulsion capacity

The procedure of Beuchat *et al*. (2000) was adopted. The sample (2 g) and 25 ml of distilled water were blended for 30 seconds using a magnetic stirrer. After complete dispersion, 25 ml refined vegetable oil was added continuously through a burette and continued the blending for another 30 s. The mixture was transferred into a centrifuge tube and was centrifuge at 1600 rpm for 5 min. The volume of oil separated from the sample after centrifugation was read directly from the tube and was recorded. The emulsion capacity was expressed as ml of oil emulsified per gram of sample (Ogunbusola *et al*., 2012). The emulsion capacity of the test sample was repeated three times for each sample and the average was calculated.

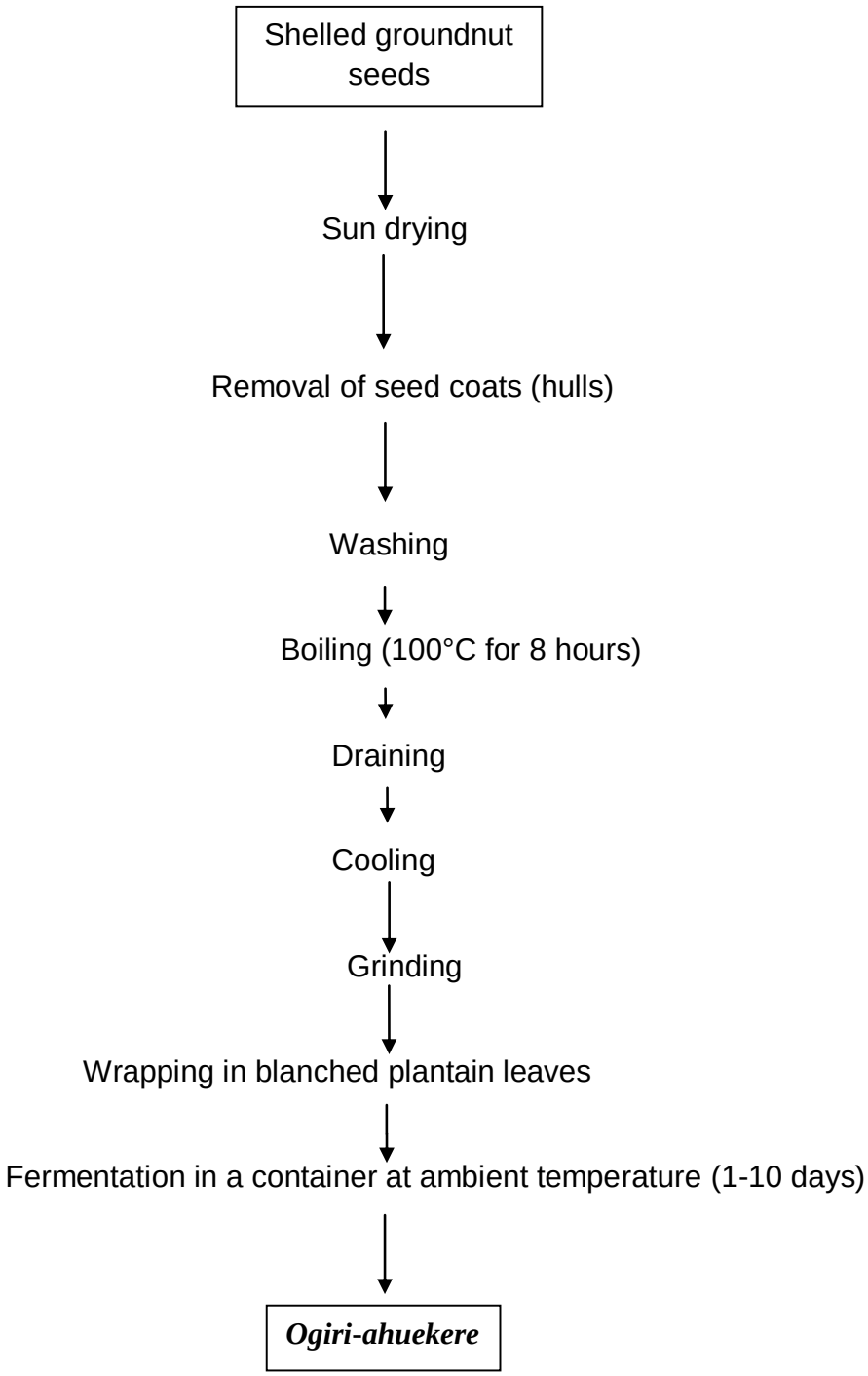

Figure 1. Flow chart for the production of fermented *ogiri–ahuekere* sample.

$$\text{Emulsion capacity} = \frac{Height\ of\ emulsified\ layer}{Height\ of\ whole\ solution\ in\ the\ centrifuge\ tube} \times 100 \quad (5)$$

Determination of swelling index

About 3 g of *ogiri* sample was put into a clean, dry, graduated 50 ml cylinder. The sample was gently leveled in the cylinder and the volume noted. 30 ml of distilled water was added to each sample. The swirled cylinder was allowed to stand for 60 min, while the change in volume was recorded every 15 min (Njoku and Banigo, 2006). The swelling index of the test sample was repeated three times for each sample and the average was calculated.

$$\text{Swelling Index} = \frac{\text{volume occupied by sample after swelling}}{\text{volume occupied by sample before swelling}} \quad (6)$$

Bulk density

Using the procedure of Onwuka (2005, 2018), about 5 g *ogiri* was put into a 10 ml measuring cylinder gently. The bottom of the cylinder was tapped gently on the laboratory bench severally until there was no further change of the sample level to a constant volume. The bulk density was calculated using the formula below. The bulk density of the test sample was repeated three times for each sample and the average was calculated.

$$\text{Bulk density} = \frac{Mass\ of\ Ogiri\ sample}{Volume\ of\ ogiri} \quad (7)$$

Determination of gelling points

The method of Narayana and Narasinga-Rao (2006) was adopted. The sample (10 g) was dispersed in distilled water, in a 250 ml beaker and made up to 100 ml. A thermometer was clamped on a retort stand with its build submerged in the suspension. With a magnetic stirrer the suspension was continuously stirred and heated. This continued until the suspension began to gel and the corresponding temperature was recorded. The bulk density of the test sample was repeated three times for each sample and the average was calculated.

Statistical analysis

The data obtained from the analyses were analyzed statistically using the Analysis of Variance (ANOVA) method with the application of SPSS Version 20. The difference between the mean values was determined by Tukey test. Significance was accepted at 5% probability level (Pallant, 2004).

DISCUSSION

Functional properties of *ogiri-ahuekere* samples fermented for 0 to 10 day(s)

Table 1 shows the functional properties of *ogiri-ahuekere* samples fermented from 0-10 day(s). The functional properties determined were water and oil absorption capacities, foaming capacity and stability, emulsion capacity, swelling index, bulk density and gelling point.

Water absorption capacity (WAC)

There was significant decrease in the water absorption capacity of the *ogiri–ahuekere* samples with increase in fermentation time (99.72 to 50.91%). The following *ogiri-ahuekere* samples had no significant differences in their WAC: unfermented and 1 day fermented samples had 99.72 and 95.92%; 2 and 3 fermented days samples had 86.12 and 80.50%; 3, 4 and 5 days fermented samples had 80.50, 76.33 and 74.87%; 6 and 7 days fermented samples had 67.27 and 62.70%; 7 and 8 days fermented samples had 62.70 and 58.10%; and 9 and 10 days fermented samples had 49.51 and 50.91%, respectively (Table 1). However, there were significant differences in the WAC among the following *ogiri-ahuekere* samples: 1 and 2 fermented samples; 2 and 4 fermented samples; 5 and 6 fermented samples; 6 and 8 fermented samples; and 8 and 9 days fermented *ogiri-ahuekere* samples respectively (Table 1). Also, WAC reduced significantly because the water binding sites present on side chain groups of protein were blocked in the lipophilic environment (Appiah *et al*., 2011; Ogunbusola *et al*., 2012; Chukwu *et al*., 2018b). The significant reduction in the WAC of the *ogiri-ahuekere* samples was due to less availability of polar amino acids. Hence, increase in fermentation time caused the decrease in the WAC of the condiments as well as makes it suitable for soup thickening (Mwasaru *et al*., 1999; 2005; Omobolanle *et al*., 2015).

Oil absorption capacity (OAC)

There were significant increases in the oil absorption capacities (72.70 - 128.43%) of the *ogiri-ahuekere* samples (Table 1). There were no significant differences in the OAC of the following *ogiri-ahuekere* samples: unfermented, 1 and 2 day(s) fermented samples which had 72.70, 76.05 and 75.10%; 3 and 4 days fermented samples which had 83.67 and 88.60%; 4 and 5 days fermented samples which had 88.60 and 91.80%; 5 and 6 days fermented samples which had 91.80 and 96.33%; 7 and 8 days fermented samples which had 109.20 and 112.10%; and 8 and 9 days fermented samples which had 112.10 and 116.75% respectively (Table 1). There were significant differences in the OAC of the following *ogiri-ahuekere* samples: 2 and 3 days fermented samples; 3 and 5 days fermented samples; 6 and 7 days fermented samples; 7 and 9 days fermented samples; and 9 and 10 days fermented samples (Table 1). This was because of the exposure of oil binding sites present on the side chain groups of proteins in a lipophilic environment as fermentation progressed (Ogunbusola *et al*., 2012). This property of condiment could enhance emulsion in soup preparation.

Foaming capacity (FC)

Table 1 shows there were significant ($p \leq 0.05$) increase in the foaming capacities (1.37 - 6.84%) of the *ogiri-ahuekere* samples due to the increase in fermentation

Table 1. Mean values of functional properties of *ogiri-ahuekere* samples fermented from 0-10 days.

Fermentation time (day)	Properties							
	WAC (%, g/g)	OAC (%, g/g)	FC (%)	FS (%)	EC (%)	SI	BD (g/m^3)	GP (°C)
0	99.72 ± 1.81^{a}	72.70 ± 0.86^{a}	1.37 ± 0.06^{a}	31.60 ± 1.38^{a}	40.87 ± 0.80^{a}	4.00 ± 0.17^{a}	0.13 ± 0.02^{a}	62.33 ± 0.58^{a}
1	95.92 ± 2.13^{a}	76.05 ± 2.36^{a}	1.38 ± 0.15^{a}	35.17 ±1.55^{b}	42.03 ± 0.67^{a}	3.03 ± 0.25^{b}	0.22 ± 0.01^{b}	65.67 ± 2.08^{b}
2	86.12 ± 2.54^{b}	75.10 ± 4.74^{a}	1.69 ± 0.03^{ab}	40.85 ± 0.34^{c}	44.07 ± 2.10^{a}	2.02 ± 0.04^{c}	0.26 ± 0.01^{bc}	69.67 ± 0.58^{c}
3	80.50 ± 1.44^{bc}	83.67 ± 2.79^{b}	1.91 ± 0.09^{b}	42.03 ± 1.10^{cd}	55.20 ± 2.07^{b}	1.90 ± 0.09^{c}	0.29 ± 0.01^{cd}	70.67 ± 0.58^{c}
4	76.33 ± 0.91^{c}	88.60 ± 1.25^{bc}	2.07 ± 0.10^{b}	44.60 ± 0.17^{de}	69.77 ± 0.65^{c}	1.18 ± 0.05^{d}	0.33 ± 0.01^{d}	71.67 ± 0.58^{cd}
5	74.87 ± 0.78^{c}	91.80 ± 3.14^{cd}	2.94 ± 0.15^{c}	47.53 ± 0.74^{ef}	72.13 ± 0.78^{c}	1.07 ± 0.07^{de}	0.39 ± 0.01^{e}	73.67 ± 0.58^{de}
6	67.27 ± 1.12^{d}	96.33 ± 1.79^{d}	3.84 ± 0.07^{d}	50.67 ± 0.59^{fg}	81.33 ± 0.74^{d}	0.96 ± 0.02^{de}	0.49 ± 0.01^{f}	75.33 ± 0.58^{e}
7	62.70 ±1.64^{de}	109.20 ± 1.48^{e}	4.14 ± 0.07^{de}	52.97 ± 0.83^{gh}	87.57 ± 0.68^{e}	0.91 ± 0.02^{de}	0.54 ± 0.05^{f}	78.33 ± 0.58^{f}
8	58.10 ± 2.80^{e}	112.10 ± 1.78^{ef}	4.45 ± 0.20^{e}	55.23 ± 0.99^{hi}	89.33 ± 0.58^{e}	0.87 ± 0.01^{e}	0.65 ± 0.01^{g}	81.00 ± 1.00^{f}
9	49.51 ± 0.93^{f}	116.75 ± 1.92^{f}	5.38 ± 0.47^{f}	56.80 ± 1.84^{i}	94.13 ± 0.21^{f}	0.83 ± 0.02^{e}	0.70 ± 0.01^{gh}	85.00 ± 1.00^{g}
10	50.91 ± 5.89^{f}	128.43 ± 3.05^{g}	6.84 ± 0.12^{g}	60.63 ± 1.10^{j}	97.47 ± 0.78^{f}	0.78 ± 0.03^{e}	0.75 ± 0.03^{h}	88.33 ± 1.16^{h}
LSD	5.972	6.138	0.453	3.304	3.874	0.304	0.063	2.892

Mean ± standard deviation of triplicates. Means with the superscripts are not significantly different from each other in the same column ($p \leq 0.05$) whereas means with different superscripts are significantly different from each other in the same column. Where: WAC = Water Absorption Capacity; OAC = Oil Absorption Capacity; FC = Foam Capacity; FS = Foam Stability; EC = Emulsion

time. Unfermented groundnut seeds had 1.37% which was significantly the same with foaming capacities (1.38 and 1.69%) of 1 and 2 day(s) fermented *ogiri-ahuekere* samples respectively; but significantly different from the FC (1.91%) of 3 days fermented *ogiri-ahuekere* sample. FC of 4 days fermented *ogiri-ahuekere* samples (2.07%) was statistically the same with the foaming capacities of 2 and 3 days fermented *ogiri-ahuekere* samples but significantly different from the FC of 5 days fermented *ogiri-ahuekere* sample (2.94%). The FC (3.84%) of 6 days fermented *ogiri-ahuekere* sample was significantly the same with the FC (4.14%) of 7days fermented *ogiri-ahuekere* sample but significantly different from the FC (4.45%) of 8 days fermented *ogiri-ahuekere* sample; though, there was no significant difference between foaming capacities of 7 and 8 days fermented *ogiri-ahuekere* samples (Table 1). Significant ($p \geq 0.05$) differences existed among foaming capacities (4.45, 5.38 and 6.84%) of 8, 9 and 10 days fermented *ogiri-ahuekere* samples respectively. The increase in fermentation time could have increased the aerating ability of the condiments in soups which could also cause increase in FC (Akintayo *et al*., 1999).

Foaming stability (FS)

Table 1 shows there was significant ($p \leq 0.05$) reduction in the foaming stability (60.63 to 31.60%) of the *ogiri-ahuekere* samples due to increase in the fermentation time. There were no significant differences in FS among the following *ogiri-ahuekere* samples: 1 and 2 day(s) fermented *ogiri-ahuekere* samples had 56.80% and 55.23%; 2 and 3 days fermented *ogiri-ahuekere* samples had 55.23% and 52.97%; 3 and 4 days fermented *ogiri-ahuekere* samples had 52.97 and 50.67%; 4 and 5 days fermented *ogiri-ahuekere* samples had 50.67 and 47.53%; 5 and 6 days fermented *ogiri-ahuekere* samples had 47.53 and 44.60%; 6 and 7 days fermented *ogiri-ahuekere* samples had 44.60 and 42.03%; and 7 and 8 days fermented *ogiri-ahuekere* samples had 42.03 and 40.85%, respectively (Table 1). However, there were significant differences in FS of the following *ogiri-ahuekere* samples: unfermented groundnut seeds and 1 day fermented *ogiri-ahuekere* samples had 60.63 and 56.80%; 1 and 3 day(s) fermented *ogiri-ahuekere* samples had 56.80 and 52.97%; 2 and 4 days fermented *ogiri-ahuekere* samples had 55.23 and 50.67%; 3 and 5 days fermented *ogiri-ahuekere* samples had 52.97 and 47.53%; 4 and 6 days fermented *ogiri-ahuekere* samples had 50.67 and 44.60%; 5 and 7 days fermented *ogiri-ahuekere* samples had 47.53 and 42.03%; 6 and 8 days fermented *ogiri-ahuekere* samples had 44.60 and 40.85%; and 8, 9 and 10 days fermented

ogiri-ahuekere samples had 40.85, 35.17 and 31.60%, respectively (Table 1). This could be attributed to the ability of protein to form and stabilize foam and is related to its amphiphilic (polar/non-polar) behaviour (Alleoni, 2006) caused by the increase in fermentation time.

Emulsifying capacity (EC)

Table 1 showed that there was significant ($p \leq 0.05$) increase in the emulsifying capacity (40.87 to 97.47%) of *ogiri-ahuekere* samples due to increase in fermentation time. There were no significant differences in the emulsifying capacity of the following *ogiri-ahuekere* samples: unfermented, 1 and 2 day(s) fermented *ogiri-ahuekere* samples had 40.87, 42.03 and 44.07%; 4 and 5 days fermented *ogiri-ahuekere* samples had 69.77 and 72.13%; 7 and 8 days fermented *ogiri-ahuekere* samples had 87.57 and 89.33%; and 9 and 10 days fermented *ogiri-ahuekere* samples had 94.13 and 97.47% respectively (Table 1). However, there were significant differences of the following *ogiri–ahuekere* samples: 2, 3 and 4 days fermented *ogiri-ahuekere* sample; 5, 6 and 7 days fermented *ogiri-ahuekere* samples; and 8 and 9 days fermented *ogiri-ahuekere* samples. This significant increase in EC could be attributed to protein being the surface active agents in fermented products can form and stabilize the emulsion by creating electrostatic interaction on oil droplets surface (Markri *et al*., 2005). In accordance with Mwasura et al. (2005), the result showed that increase in fermentation time made *ogiri–ahuekere* to possess a good emulsifying property that could serve as a vital source of soup emulsification (Omobolanle *et al*., 2015 and Chukwu *et al*., 2018b).

Swelling index (SI)

Table 1 showed that there were significant ($p \leq 0.05$) decrease in the swelling index (4.00 to 0.88) of the *ogiri–ahuekere* samples. There was no significant differences in the swelling index of the following *ogiri–ahuekere* samples: 2 and 3 days fermented *ogiri-ahuekere* samples which had 2.02 and 1.90; 4, 5, 6 and 7 days fermented *ogiri-ahuekere* samples which had 1.18, 1.07, 0.96 and 0.91; and 8 to 10 days *ogiri–ahuekere* samples that had 8 days (0.87), 9 days (0.83) and 10 days (0.78), respectively. However, there were significant differences in the swelling indexes of the following *ogiri–ahuekere* sample: unfermented, 1 and 2 day(s) *ogiri–ahuekere* samples had 4.00, 3.03 and 2.02; 3 and 4 days *ogiri–ahuekere* samples had 1.90 and 1.18; 4 and 8 days *ogiri–ahuekere* samples had 1.18 and 0.87, respectively. This could be attributed to the fact that unfermented groundnut seeds had more of intermolecular carbohydrates bound (Chukwu *et al*., 2018b) which allowed it to absorb more water to swell than the fermented samples (Adebowale and Maliki, 2011).

Bulk density (BD)

There were significant improvements in the bulk density (0.13 to 0.75 gm^{-3}) of the *ogiri–ahuekere* samples due to the increase in fermentation time (Table 1).There were no significant differences in the bulk density of the following *ogiri–ahuekere* samples: 1 and 2 day(s) *ogiri–ahuekere* samples which had 0.22 and 0.26 gm^{-3}; 2 and 3 days *ogiri–ahuekere* samples which had 0.26 and 0.29 gm^{-3}; 3 and 4 *ogiri–ahuekere* days samples that had 0.29 and 0.33 gm^{-3}; 6 and 7 days *ogiri–ahuekere* samples had 0.49 and 0.54 gm^{-3}; 8 and 9 days *ogiri–ahuekere* samples had 0.65 and 0.70 gm^{-3}; and 9 and 10 days *ogiri–ahuekere* samples had 0.70 and 0.75 gm^{-3}, respectively (Table 1). However, there were significant differences in the bulk density of the following *ogiri–ahuekere* samples: unfermented and 1 day *ogiri–ahuekere* samples; 2 and 4 days *ogiri–ahuekere* samples; 4, 5 and 6 days *ogiri–ahuekere* samples; 7 and 8 days *ogiri–ahuekere* samples; 8 and 10 days *ogiri–ahuekere* samples. Also, more compact products are easier to package, and have lower packaging cost (Oluwatoyin *et al*., 2002).

Gelling points (GP)

There was significant ($p \leq 0.05$) increase in gelling point (62.33 to 88.33°C) of the *ogiri-ahuekere* samples (Table 1). There were no significant differences in the gelling point temperature of the following *ogiri–ahuekere* samples: 2 and 3 days *ogiri–ahuekere* samples which had 65.67 and 69.67°C; 4 and 5 days *ogiri–ahuekere* samples which had 70.67 and 71.67°C; 5 and 6 days *ogiri–ahuekere* samples which had 71.67 and 73. 67°C; and 6, 7 and 8 days *ogiri–ahuekere* samples which had 73.67, 75.33 and 78.33°C, respectively (Table 1). However, there were significant differences in gelling points of the following *ogiri– ahuekere* samples: unfermented 1 and 2 day(s) *ogiri–ahuekere* samples; 3 and 4 days *ogiri–ahuekere* samples, 4 and 6 days *ogiri–ahuekere* samples; 5 and 7 days *ogiri–ahuekere* samples; and 9 and 10 days *ogiri–ahuekere* samples respectively (Table 1). Akintayo *et al*. (1999) reported that the lower the gelling point/temperature, the better the gelling ability of samples because the gels are aggregates of denatured protein molecule during boiling. This implies that increase in fermentation time could increase the gelling point of the *ogiri–ahuekere* samples. The unfermented *ahuekere* possessed a good gelling point which implies that when boiled moderately would be good for soup preparation (Ibeabuchi, 2014).

CONCLUSION

The effect of fermentation time on functional properties of *ogiri-ahuekere* condiment was studied. The results obtained showed that increase in fermentation time caused

significant decrease in the following functional properties such as water absorption capacity (99.72 to 49.51%), foaming stability (60.63 to 31.60%), and swelling index (4.00 to 0.78), whereas the increase in fermentation time caused significant increase in the following functional properties: oil absorption capacity (72.70 to 128.43%), foaming capacity (1.37 to 6.84), emulsifying capacity (40.87 to 97.47%), bulk density (0.13 to 0.75 gm^{-3}) and gelling point (62.33 to 88.33°C). This showed that increase in the fermentation time improved the functional properties of the *ogiri-ahuekere* samples.

RECOMMENDATION

Further work is recommended on product (*ogiri-ahuekere*) types in various forms such as cubes, granular and liquid. This will enhance packaging, storage, distribution and marketability of the product. The use of starter culture could be applied to reduce fermentation time and probably improve the quality of the product.

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