International Food Research Journal 24(2): 614-620 (April 2017)
Journal homepage: *http://www.ifrj.upm.edu.my*

# Effect of drying method on nutritional composition, sensory and antimicrobial properties of Ginger *(Zinginber officinale)*

*Ajayi, O.A., Ola, O.O. and Akinwunmi, O.O.

[1]*Department of Food Science and Technology, Faculty of Agriculture, Bowen University, Iwo, Nigeria*

**Article history**

*Received: 7 July 2015*
*Received in revised form: 7 January 2016*
*Accepted: 11 July 2016*

**Keywords**

*Sun oven dried ginger*
*Microwave dried ginger*
*Nutrient composition*
*Sensory*
*Antimicrobial*

**Abstract**

Ginger plant is rich in minerals, vitamins, dietary fiber and it possess various medicinal and health benefits. Ginger rhizomes have a short shelf-life, making drying an essential processing method to improve storability. The focus of this study was evaluating the effect of different drying methods on the nutritional composition of ginger. Four drying methods: solar box (SB), sun oven plus solar box (SOSB), conventional (CO) and microwave oven (MO) were employed. Sensory analysis and antimicrobial capacity of dried and milled ginger were also performed. Data analysis and associations between drying methods, nutritional composition and sensory attributes were explored. Results show the nutritional composition of fresh ginger sample for moisture, protein, ash, crude fiber and fat were 73.83%, 4.37%, 1.30%, 1.60% and 2.10% respectively. For dried samples, CO had the lowest moisture (5.1%); SB had the highest ash (4.6%); MO, SOSB and CO had the highest protein (11.3%); CO had the highest fiber (5.1%) and CO also had the highest fat (6.8%) contents. These values were all significantly different from ($p<0.05$) the control. For sensory, MO sample scored (7.6) the highest for appearance while the least score for appearance was for oven dried samples (5.3). The panelists preferred the color of the microwave samples and raw samples both having a mean score of (7.2). The general acceptability was highest in the microwave dried samples (7.6). There were relationships between method of drying, nutritional composition and appearance of the resultant dried ginger powder. Finally, dried ginger is effective against tested microorganisms. In conclusion, microwave oven drying method maintained high nutritional content and is most preferred by the panelists.



## Introduction

Ginger (*Zinginber officinale* Rosc.), is an underground rhizome plant originally from India and now cultivated in several other parts of the world including Nigeria. Ginger has been the focus of many studies and a lot has been discovered, such as its nutritional content (Shahid and Hussain, 2012; Ajayi *et al.*, 2013), use and importance in folk medicine (Okwu, 2004; Peggy, 2006); relief for common cold, headaches and cramps (Altman and Marcussen, 2001; Hawkins and Ehrlich, 2007). Furthermore, ginger has been documented to possess essential oil and the antimicrobial capabilities (Martins *et al.*, 2001; Menon and Sasidharan, 2010; Zhao *et al.*, 2011). Nigeria although ranked first in the world in terms of percentage of total hectares of ginger under cultivation, the output is low (NdaNmadu and Marcus, 2013), ultimately leading to her being the fifth producer (Ayemibo, 2008) and the third exporter of dried ginger after India and China (Eze and Agbo, 2011). One of the major set-back for ginger growers is rapid deterioration and loss of nutrient of ginger during storage. According to reports, although Nigeria produces high quality ginger (Njoku *et al.*, 1995), she produces below standard dry ginger (Onu and Okafor, 2003) most probably due to drying method employed.

One of the oldest forms of preservation of foods is drying. Furthermore, drying is essential for agricultural crops in developing countries (Eze and Agbo, 2011) in order to minimize spoilage and decay, improve shelf-life of the crop as well as minimize economic loss to farmers. The primary objective of drying is the removal of water from foods, which microorganisms require for growth, resulting in a more shelf stable, smaller and lighter food. Reduction in moisture discourages growth of spoilage or pathogenic microorganisms (Boyer and Huff, 2008). Furthermore, drying of herbs and spices is also used generally to extend the shelf-life of the resulting dried products.

There are several methods of drying including sun or solar, conventional, microwave oven and the

*Corresponding author.
Email: *sunmbo.ajayi@gmail.com*

use of food dehydrator. Solar energy is a result of thermonuclear reactions of fusion from "hydrogen" into "helium" taking place in the sun (Balakrishnan *et al*., 2012), further, it is a direct transformation of solar UV light rays from sunlight to heat to infrared light rays, which causes the water, fat and protein molecules to vibrate and heat up (Diffey, 2002). There are different forms of solar drying, namely: traditional, solar box and sun oven. Traditional sun drying is low/no cost and crops are exposed to the environment. It is the preferred choice of drying for farmers in developing countries because of

finance. This method of drying however is froth with many challenges including unpredictable weather, infestation of insects, pests and microbial contamination (Fellows *et al.*, 1995; Ekechucwu, 2010), and it poses a food safety problem for consumers. Solar box is a box fabricated with wood and glass cover of varying sizes while sun oven is a box with reflective panels. Food is placed in a pan painted black in the box. Both solar box and sun oven are left outside to absorb energy from the sun and are safer alternatives to the traditional concrete floor, open air drying and more beneficial. Although solar box and sun oven drying are equally affected by weather as the traditional drying, they are not plagued by pests' problems. Conventional drying uses electricity and is the most practical and reliable. However, due to high cost and epileptic supply of electricity low scale farmers in developing countries cannot afford this method of food drying.

Microwave oven also uses electricity, heating the food with electromagnetic radiations which excite the molecules in the food, transmitting heat from the edge to center of food. Microwave oven is recently being used for drying different spices (Sangwan *et al.*, 2012; Danso-Boateng, 2013).

As reported by many researchers, there is an increasing trend of multiple drug resistant microorganisms worldwide (Livermore, 2000; Ajayi *et al*., 2009). Plants have various polyphenolic compounds (Balunas and Kinghorn, 2005; Kim *et al*., 2005) and spices including ginger contain essential oils that have been shown to have antimicrobial properties (Beuchat and Golden, 1989; Ahmed *et al*., 2012; Suhad *et al*., 2012). However, drying has been documented to cause substantial reduction in essential oil content due to the temperature of drying, in Basil (Danso-Boateng, 2013) and other plant materials which could lead to reduction of antimicrobial activity of the dried products (Benbelaid *et al*., 2013). To our knowledge, there is no information as to the drying method that preserves most of the nutritional quality of ginger after drying. Therefore, the objectives of this study were 1) to determine the nutritional composition of ginger dried by different methods, 2) to perform sensory analysis and antimicrobial capability of dried ginger products 3) to evaluate the strength of association between methods of drying, proximate composition and sensory attributes.

## Materials and Methods

Fresh ginger rhizomes were obtained from Bodija market, Ibadan, Oyo State, Nigeria. They were sorted to remove roots, leaves and other debris and washed properly with distilled water before analysis. About 500 g of ginger was weighed for each of the four drying methods. Cleaned rhizomes were blanched and sulphitted according to Sangwan *et al.* (2012). Briefly, weighed rhizomes were blanched for 10-15 seconds and immersed in 0.2% Potassium metabisulphite (Park Scientific Ltd. Northampton, UK) for 5 minutes. Unpeeled treated ginger rhizomes were cut into small chunks and dried in 800W microwave oven (Haier Thermocool, USA) at power 5. Sample placed in a conventional laboratory oven (Gen Lab, Widens, England) was dried at a temperature of 50ºC; Sun oven sample was placed in a black rectangular pan without dehydrating rack (Sun Ovens International, Inc. IL. USA) and sample was spread out in the solar box. Both sun oven and solar box samples were placed outside. All drying was done according to Sangwan *et al.* (2012), with slight modifications in duration of drying. Immediately after drying samples were placed in the desiccator until cool then peeled and milled using a blender (Haier thermocool Inc. China), and packed in air-tight container until analyzed. Blanched, sulphitted, but un-dried ginger sample served as the control.

*Proximate analysis*

Proximate compositions of the dried and undried ginger were performed as described by AOAC, (1990) methods. Moisture, ash, crude fiber, fat, protein contents were determined in triplicate. The carbohydrate content was determined by subtracting the sum of the nutrient composition from 100.

*Sensory analysis*

Sensory analysis was carried out by 10 untrained judges but who were familiar with the product. Judges consisted of 8 female and 2 male Lecturers and Students from the Department of Food Science and Technology, Bowen University, Iwo, Osun State. The panel was instructed before the commencement of the evaluation and was asked to evaluate quality attributes such as flavor, color, aroma appearance and

general acceptability of the products. The samples were coded and about 2 g of each sample placed in a transparent plate was randomly presented and scored on a 9-point hedonic scale from (like extremely = 9 to dislike extremely 1).

*Antimicrobial Testing*

Antimicrobial activity of the control and dried ginger was studied according to Kirby-Bauer disc diffusion method (Bauer *et al.*, 1996).

*Extraction of ginger*

About 20 g of (SB and SOSB) dried; 16 g of (MO) dried and 40 g of raw milled ginger were extracted in 100 ml of 95% ethanol, overnight at room temperature (30 ± $2^0$C) with occasional agitation according to Malu *et al*. (2009). The extracts were then filtered using Whatman No. 1 filter paper following overnight incubation and concentrated to 20 ml in a water bath. This was regarded as 100% concentration of the extract. A 25% concentration was prepared 1:3 (v/v) ginger extract: DI water and used for antimicrobial study.

*Preparation of bacteria inoculum*

Test organsms *Salmonella* spp., *Staphylococcus epidermidis* and *Staphylococcus aureus* were previously isolated from meat sample. The organisms were characterized by colony morphology, Gram stain, growth on selective media and biochemical tests (Pollack *et al*., 2002). The organisms were grown and stored in nutrient agar slant at room temperature (30 ± $2^0$C) until used. Nutrient broth was cultured with the bacteria to be analyzed overnight until the inoculum density equivalent to a 0.5 McFarland turbidity standard was obtained.

*Disk diffusion method*

Discs of 6 mm in diameter were prepared from Whatman No. 1 filter paper and sterilized before use. Each isolate was streaked on to Mueller-Hinton agar plate and allowed to air-dry for 10 minutes at room temperature. Triplicate discs impregnated with 20 µL of 25% concentration ginger extracts were aseptically placed on the Mueller-Hinton streaked plates and incubated for 18 h at $37^0$C. Zones of inhibition were measured in mm after incubation.

*Statistical analysis*

Data collected from the proximate and sensory analyses were analyzed using Statistical Package for the Social Sciences (SPSS) (2011). Analysis of Variance (ANOVA) was used to evaluate significant differences ($p<0.05$). Tukey's Studentized test was used for the separation of means. Spearman's correlation coefficient was performed to evaluate the strength of association between method of drying, nutritional content and sensory attributes of dried ginger.

## Results and Discussion

*Proximate composition*

Drying in the microwave oven was for 19 minutes, while solar box drying was carried out for 2 days between 10:00 am and 6:00 pm. Sun oven sample was dried for 4 hours with temperature ranging from at 93 -$149^0$C, at the time of drying and further dried in the solar box for 1 day because sun oven actually cooked the ginger. Conventional oven sample was dried for 9 hours. Results of undried (control) and dried powdered ginger for moisture, ash, crude fiber, protein and fat contents are shown in Table 1. Overall, there were statistical differences ($p<0.05$) between the values recorded for control and dried ginger.

The moisture content of blanched, sulphited but undried ginger (control) was 73.8% and statistically different ($p<0.05$) from the moisture content of the dried ginger powder. Although Sangwan *et al.* (2012) did not report the moisture content of the un-dried ginger, the value in this study is in agreement with the reported values of (76.86%) and (74.7%) by Odebunmi *et al.* (2009) and Okolo *et al.* (2012) respectively. Percent moisture contents recorded for microwave, sun oven plus solar box, solar box and conventional oven dried ginger were (9.5%), (7.1%), (6.5%) and (5.1%) respectively. The conventional oven was more effective in removing moisture compared to other drying methods. This was also observed by other researchers (Bankole *et al*., 2005; Eze and Akubor, 2012). The heat supplied by the conventional oven is more consistent than the sun which depended on the climate and season at the time of drying (Bankole *et al*., 2005). Therefore, differences in moisture content were because of different drying methods. Drying as expected reduced the moisture content of ginger. Furthermore, it is an indication that the shelf life of the product would be extended and that deterioration due to microbial growth would be limited (Patel and Srinivasan, 2004). The ash content of raw ginger was 1.3% and lower than the dried samples. Ash content of the dried samples for solar box was (4.6%), sun oven plus solar box (4.5%), conventional oven (4.3%), microwave (4.1%). This result corresponds with (1.0%) for raw and (4.0%) for sun and oven dried ginger reported by Shirshir *et al.* (2012). Therefore, dried ginger could

Table 1. Mean proximate composition of raw (control) and ginger dried by various methods

| Nutrient composition | Method of drying | | | | |
|---|---|---|---|---|---|
| | Control | MO* | SB | SOSB | CO |
| Moisture | 73.8± 1.2$^{a}$ | 9.5± 2.29$^{b}$ | 6.5± 0.50$^{c}$ | 7.1± 0.76 $^{bc}$ | 5.1± 0.28$^{c}$ |
| Ash | 1.3± 0.28$^{b}$ | 4.1± 0.28$^{a}$ | 4.6± 0.28$^{a}$ | 4.5± 0.86$^{a}$ | 4.3± 0.28$^{a}$ |
| Fiber | 1.6± 0.28$^{b}$ | 5.0± 0.86$^{a}$ | 4.3± 1.04$^{a}$ | 4.3± 0.28$^{a}$ | 5.1± 0.76$^{a}$ |
| Protein | 4.3± 0.38$^{c}$ | 11.4 ±.04$^{a}$ | 9.26± 0.21$^{b}$ | 11.2± 0.19$^{a}$ | 11.3± 0.04$^{a}$ |
| Fat | 2.1± 0.10$^{b}$ | 4.3± 0.95$^{b}$ | 3.8± 0.47$^{b}$ | 4.1± 0.96$^{b}$ | 6.8± 1.45$^{a}$ |
| Carbohydrate | 16.7± 1.7$^{c}$ | 65.6± 2.4$^{b}$ | 71.4± 0.84$^{a}$ | 68.7± 0.85$^{ab}$ | 67.2± 0.71$^{b}$ |

Values are mean ± SD of 3 replicates. Test values along the same row carrying different superscripts for each parameter are significantly different ($p < 0.05$) according to Tukey's test. *MO=Microwave oven; SB=Solar box; SOSB=Sun oven + Solar box; CO=Conventional oven.

Table 2. Spearman's ρ Correlation Coefficient between methods of drying and nutritional composition of powdered ginger

| | Moisture content | Ash content | Crude fiber | Protein content | Fat content |
|---|---|---|---|---|---|
| Method of drying | ρ(15) = -724** (P<0.05) | ρ(15) = .397 | ρ(15) =.651** (P<0.01) | ρ(15) =.668** (P<0.01) | ρ(15) =.814** (P<0.01) |
| Moisture content | | ρ(15) = -.599* (P<0.05) | ρ(15) = -.552* (P<0.01) | ρ(15) = -.371 (P>0.05) | ρ(15) = -.787** (P<0.01) |
| Fiber content | | | | ρ(15) =.676** (P<0.01) | ρ(15) = .605* (P<0.01) |
| Fat content | | | | ρ(15) = .544* (P<0.01) | |

*, ** Correlation is significant at the .05 and .01 (2-tailed)

be a potential source of minerals.

Crude protein content for raw ginger was significantly different ($p<0.05$) compared to dried samples. Values ranged between (4.5%) for raw, (9.1%) solar box, (11.4%) microwave, (11.4%) sun oven plus solar box and (11.3%) for conventional oven dried samples. There were significant statistical ($p<0.05$) differences between protein content of solar dried ginger and other drying methods. This could be due heat intensity and longer period of drying in the solar box. The protein contents of the other drying methods however, is comparable to (12.6%) reported by Bhat *et al.* (2010) and Ajayi *et al.* (2013), but higher than the values of (8.75%) and (7.3%) reported by Odebunmi *et al*. (2009) and Shirshir *et al*. (2012).

Result of crude fiber was (1.6%) for the raw and was significantly different compared to (4.3%) solar box and sun oven plus solar box, (5.0%) microwave and (5.1%) for conventional oven. The fat content of (6.8%) for conventional oven dried sample was significantly higher and different from other forms of drying. Values of (4.3%); (4.1%); (3.8%); (2.1%) were recorded for microwave, sun oven plus solar box, solar box and control respectively (Table 1).

Carbohydrate content of solar box dried ginger was (71.37%) and significantly higher compared to the other forms of drying, sun oven plus solar box (68.68%), conventional (67.16%), microwave (65.56%) and (16.74%) control samples. The result show high carbohydrate content of ginger and according to Otunla *et al.* (2010), ginger can be

Table 3. Spearman's ρ Correlation Coefficient between methods of drying and sensory attributes of powdered ginger

| | Sensory Attributes | | | | |
|---|---|---|---|---|---|
| | Appearance | Aroma | Colour | Texture | Acceptability |
| Method of drying | ρ(50)=-.284* p<0.05 | | | | |
| Appearance | | ρ(50)=.454** p<0.01 | ρ(50)=.483** p<0.01 | ρ(50)=.458** p<0.01 | ρ(50)=.693** p<0.01 |
| Aroma | | | ρ(50)=.356* p<0.01 | ρ(50)=.392** p<0.01 | ρ(50)=.495** p<0.01 |
| Colour | | | | ρ(50)=.632** p<0.01 | ρ(50)=.756** p<0.01 |
| Texture | | | | | ρ(50)=.704** p<0.01 |

*, ** Correlation is significant at the .05 and .01 (2-tailed)

ranked as carbohydrate rich spice.

Calculated Spearman correlation coefficient results show that there are relationships between the method of drying and the resulting moisture, ash, crude fiber, crude protein and fat contents of the dried ginger powders as shown in Table 2. A strong and significant correlation ($p<0.01$) was found between method of drying and moisture, crude fiber, protein and fat content, while the relationship between method of drying and ash content was weak.

*Sensory analysis*

Results of sensory evaluation on the dried ginger powders using 9 point hedonic scale and 10 untrained panelists are presented in Figure 1. None of the samples evaluated received a maximum score of 9 in all attributes evaluated. Microwave oven dried ginger scored higher in all the attributes (appearance, colour, aroma, texture and general acceptability), followed by sun oven plus solar box drying. Results of aroma show a more clustered score for sun oven plus solar box ($6.5^{ab}\pm1.71$), conventional oven dried ($6.30^{ab}\pm1.63$) and raw ($6.8^{a}\pm1.39$) ginger while solar box drying scored the least (5.4b±1.94) (Figure 1). Microwave oven and sun oven plus solar box dried ginger were scored higher by the panel than other dried ginger and raw sample in terms of general acceptability of ginger.

These results are in agreement with Sangwan *et al.* (2012) for microwave dried ginger but their study also reported higher score for conventional dried ginger which is a deviation from this study. The method of drying strongly affected the appearance of the dried ginger and Spearman rho show association between methods of drying and appearance, which in turn generated relationships between appearance, aroma, colour, texture and general acceptability of the dried ginger powders as reported in Table 3.

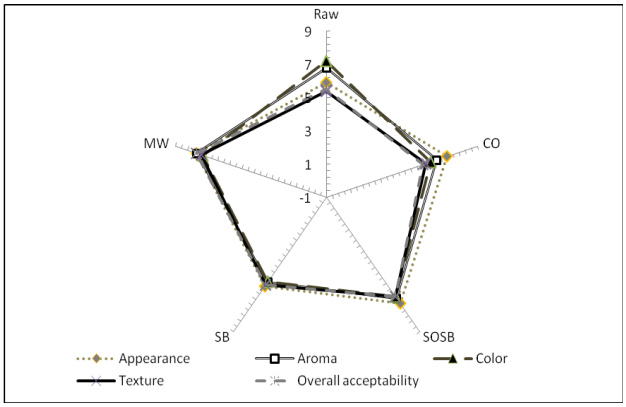


Figure 1. Sensory attributes of dried ginger from different drying methods.
Raw= control; CO=conventional oven; SB=solar box; SOSB=sun oven plus solar box; MW=microwave oven

*Antimicrobial properties*

The antimicrobial capability of the dried ginger against *Salmonella* spp., *Staphylococcus epidermidis* and *Staphylococcus aureus* were tested and the results are shown in Table 4. All of the ginger extract had antimicrobial capability. Furthermore, the various drying methods have not removed the antimicrobial capacity of ginger. Control sample was more effective against *Salmonella* spp. while the solar box dried ginger was more effective against *Staphylococcus aureus* isolate tested. Control and dried ginger had similar effect against *Staphylococcus epidermidis*. Results show that ginger generally is more potent

Table 4. Antimicrobial capability of ginger dried by different methods

| Method of drying | Conc. of extract (%) | Zone of inhibition* | | |
|---|---|---|---|---|
| | | *Salmonella spp.* | *Staphylococcus epidermidis* | *Staphylococcus aureus* |
| Raw (Control) | 25 | 7.67±1.2 | 6.67±0.6 | 6.33±.58 |
| Sun oven + solar box | | 6.0±0.0 | 6.67±0.6 | 7.0±0.0 |
| Conventional oven | | NDa | ND | ND |
| Solar box | | 6.0±0.0 | 6.67±0.6 | 8. 33±1.5 |
| Microwave oven | | 6.0±0.0 | 6.3±0.7 | 7.67±.58 |

* zone of inhibition is in mm; NDa = Not Determined

against Gram positive bacteria than Gram negative comparable with other studies (Suhad *et al.* 2012).

## Conclusion

In conclusion, results obtained from this study show that drying affects the nutritional quality and the appearance of ginger. Drying reduced the moisture content, improving the shelf stability of the product while ash, fat, fiber, protein and carbohydrate contents increased. Microwave oven drying method maintained high nutritional content and is most preferred by the panelists. Microwave oven is a viable method of drying with minimal processing time therefore preserving the nutrients in ginger. Sun oven plus solar box drying is a good option for farmers in the developing countries because it utilizes sun energy not electricity to dry.

Furthermore, there are associations between method of drying and nutritional content of the dried ginger. In addition, the method drying affects the appearance of dried ginger samples. There were strong and positive association between appearance and aroma, colour, texture and general acceptability of the dried ginger powder. Dried ginger is effective against some bacterial growth particularly Gram positive *Staphylococcus* isolates.

## References


Ajayi, O.A., Williams, L.L., Oluwoye, J. and Johnson, J.U. 2009. Antimicrobial resistance testing of *Staphylococcus* isolates with Spiral Gradient Endpoint Technology. International Journal of Science in Society 1: 60-69.

Ajayi, O.B., Akomolafe, S.F. and Akinyemi, F.T. 2013. Food value of two varieties of ginger *(Zingiber officinale)* commonly consumed in Nigeria. Hindawi 2013: 1-5.

Altman, C.D. and Marcussen, K.C. 2001. Effect of a ginger extract on knee pain in patient with osteoarthritis. Arthritis Rheumatology 44(11): 2531- 2538.

AOAC. 1990. Association of Official Analytical Chemists. Official methods of analysis 14th edition. Arlington, VA.

Ayemibo, B. 2010. World commodity export volume ranking: Ginger. downloaded from *www.tradeinfong.com/2010/11/world-commodity-export-volume.html* on 12/2/2015.

Balakrishnan, M., Claude, A. and Arun Kumar, D.R. 2012. Engineering, design and fabrication of a solar cooker with parabolic concentrator for heating, drying and cooking purposes. Archives of Applied Science Research 4(4): 1636—1649.

Balunas, M.J. and Kinghorn, A.D. 2005. Drug discovery from medicinal plants. Life Sciences 78(5): 431-441.

Bankole, S.A., Osho, A., Joda, A.O. and Enikuomehin, O.A. 2005. Effect of drying method on the quality and storability of 'egusi' melon seeds (*Colocynthis citrullus* L.). African Journal of Biotechnology 4(8): 799-803.

Bauer, A.W., Kirby, W.M.M., Sherris, J.C. and Turck, M. 1996. Antibiotic susceptibility testing by a standardized single disc method. American Journal of Clinical Pathology 45(4): 493-496.

Benbelaid, F., Abdoune, M.A. Khadir, A. and Bendahou, M. 2013. Drying effect on yield and antimicrobial activity of essential oils. International Journal of Medicinal and Aromatic Plants 3(1): 93-101.

Boyer, R. and Huff, K. 2008. Using Dehydration to Preserve Fruits, Vegetables, and Meats. Virginia Cooperative Extension Publication 348-597.

Danso-Boateng, E. 2013. Effect of drying methods on nutrient quality of Basil *(Ocimum viride)* leaves cultivated in Ghana. International Food Research Journal 20(4): 1569-1573.

Diffey, B.L. 2002. Sources and measurement of ultraviolet radiation. Methods 4-13.

Ekechukwu, V.O. 2010. Solar Drying Technology: An

overview Paper. Presented at FUTO Alternative Energy Conference, Federal University of Technology Owerri.

Eze J.I. and Akubor P.I. 2012. Effect of drying methods and storage on the Physicochemical properties of Okra. Journal of Food Process Technology 3(88): 173- 177.

Eze, J.I. and Agbo, K.E. 2011. Comparative studies of sun and solar drying of peeled and unpeeled ginger. American Journal of Scientific and Industrial Research 2(2): 136-143.

Fellows, P., Axtell, B. and Dillon, M. 1995. Quality assurance for small-scale rural food industries. FAO Agricultural Services Bulletin No. 117.

Hawkins, E.B. and Ehrlich, S.D. 2007. Herbal medicine: Overview, Available from: *http://www.umm.edu/ altmed/articles/herbal-medicine-000351. htm.* [Last accessed on 2014 June].

Kim, Y.S., Hwang, C.S. and Shin, D.H. 2005. Volatile constituents from the leaves of *Polygonum cuspidatum* S. et Z. and their anti-bacterial activities. Food Microbiology 22(1): 139-144.

Livermore, D.M. 2000. Antibiotic resistance in Staphylococci. International Journal Antimicrobial Agents 16: 3-10.

Martins, A.P., Salgueiro, L., Goncalves, M.J., Proenca da Cunha, A., Vila, R., Canigueral, S., Mazzoni, V., Tomi, F. and Casanova, J. 2001. Essential oil composition and antimicrobial activity of three zingiberaceous from S. Tome e Principe. Planta Medica 67(6): 580-584.

Menon, A.N. and Sasidharan, I. 2010. Comparative chemical composition and antimicrobial activity fresh and dry ginger oils (*Zingiber officinale* Roscoe). International Journal of Current Pharmaceutical Research 2(4): 40-43.

NdaNmadu, J. and Marcus, P.L. 2013. Efficiency of Ginger production in selected local government areas of Kaduna State, Nigeria. International Journal of Food and Agricultural Economics 1(2): 39-52.

Njoku, B.O., Mbanaso, E.N.A. and Asumugha, G.N. 1995. Ginger production by conventional and tissue culture techniques. Dolf Publishers, Owerri, Imo State, p.13-14.

Okwu, D.E. 2004. Phytochemicals vitamins and mineral contents of indigenous spices of South Eastern Nigeria. Journal of Sustain Agricultural Environment 6: 30-34.

Onu, L.I. and Okafor, G.I. 2003. Effect of physical and chemical factor variations on the efficiency of mechanical slicing of Nigerian ginger (*Zingiber officinale* rose). Journal of Food Engineering 56: 43-47.

Pollack, R.A., Findlay, L., Mondschein, W. and Modesto, R.R. 2002. Laboratory Exercises in Microbiology. 2nd edition. John Wiley and Sons Inc. USA. p. 51-53; 112; 257.

Sangwan, A., Kawatra, A. and Sehgal, S. 2012. Nutritional composition of ginger powder prepared using various drying methods. Journal of Food Science Technology 51(9): 2260-2262.

Shahid, M. and Hussain, F. 2012. Chemical composition and mineral contents of Zingiber officinale and *Alpinia allughas* (Zingiberaceae) rhizomes. International Journal of Chemical and Biochemical Sciences 2: 101-104.

Suhad, A.A., Iman, J.I. and Hamssah, E.A.W. 2012. Study the antibacterial activity of *Zingiber officinale* roots against some of pathogenic bacteria. Al-Mustansiriya Journal of Science 23(3): 63-70

Trowbridge Filipone, P. 2006. Ginger facts, selection and storage information. Downloaded from *http: homecooking.about.com/ Food Facts*, Selection and Storage on 12/2/2015.

Zhao, X., Yang, Z.B., Yang, W.R., Wang, Y., Jiang, S. Z. and Zhang, G. G. 2011. Effects of ginger root on laying performance and antioxidant status of laying hens and on dietary oxidation stability. Poultry Science 90: 1720 – 1727.