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Research Article: Analytical Study to Screen the Quality of Ginger Slices using Different Drying Methods with Various Chemical Pre-Treatments

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Abstract:
Fresh ginger rhizomes were washed, sorted, peeled to remove the cork skin and manually sliced into desired sizes (4 mm thickness) using a knife. The ginger slices were divided into three equal weight (each of 1.5 kg), pre-treated before solar, oven or ambient drying by dipping in three (3) food chemicals; 2% calcium oxide, 2% citric acid and 2% sodium meta bi-sulphite at 3 minutes interval and dried using solar dryer (36 h), oven dryer (28 h) and ambient (45 h) drying methods. The proximate and microbial qualities were analyzed using standard methods. The result shows that the moisture value (content) (MC) of fresh sample (79.6%) is higher than all dried samples. In sodium meta bisulphate treated samples, MC of oven dried sample (5.15%) is lower than solar and ambient dried samples (6.50, 6.62%). In citric acid treated samples, MC of oven dried sample (5.23%) is lower than ambient and solar dried samples (6.36, 6.52%). In calcium oxide treated samples, MC of oven dried sample (5.12%) is lower than ambient and solar dried samples (5.97, 6.24%). The protein content (PC) of fresh sample (5.58%) is lower than all dried samples. In sodium meta bisulphite treated samples, PC of oven dried sample (8.42%) is lower than solar and ambient dried samples (9.35, 9.02%). In citric acid treated samples, PC of oven dried sample (7.60%) is lower than ambient and solar dried samples (9.14, 9.02%). In calcium oxide treated samples, PC of oven dried sample (6.86%) is lower than ambient and solar dried samples (9.09, 8.87%). The total viable count (TVC) of sodium meta bisulphite treated oven dried sample (1.90 × 102cfu/g) was lower than solar and ambient dried samples (2.01 × 102, 2.10 × 102). The mould count of sodium meta bisulphite treated oven dried sample (1.10 × 10) was lower than solar and ambient dried samples (2.0 × 10, 4.20 × 10). Ambient dried samples had higher microbial load than oven and solar dried samples. Sodium meta bisulphate and citric acid reduced microbial activities when compared to calcium oxide. Solar dried samples were preferred over oven and ambient dried samples in all sensory attributes.

Keywords: Quality, ginger slices, drying methods, chemical, pre-treatments

1. Introduction:

Ginger (Zingiber officinals roscoe) is an ancient vegetable and spice cash crop that is coveted for its uses both as a healing plant and as a spice in cooking (Bomben et al., 2013). Large percentage of the ginger is exported to China, Chad, Sudan and Ghana while the remaining is sold mainly in the northern states (Fumen et al., 2003). Dried ginger is used both as a spice and medicine, it contains an essential oil which imparts an aroma, an oleoresin responsible for the pungent smell, starch, gums, proteins, carbohydrate, mineral matter, and fiber (Okafor, 2007). Ginger products includes essential oil in cooking, green ginger, oleoresin, dried, medicinal or cosmetic products. Immediately harvested and dried ginger during storage experiences some post harvest losses (qualitative and quantitative) due to difficulty in maintaining the maximum temperature and humidity conditions (13-15 °C and 90-95%), respectively. In solving these issues of post-harvest issues, several researches have investigated the possible effects of application of suitable food chemical pre-treatment in preservation of ginger. Ginger and its products have varied applications in culinary preparation, bakery products, toiletry products, perfume industries, meat products, wine, and soft drinks making (Fumen et al., 2003). It is termed as an important medicine to cure many diseases, such as rheumatism, piles, dyspepsia, alcoholic gastritis, fabric disease, throat problems, cholera morbus, neuralgia, and pulmonary and catarrhal diseases, it is expected that the world demand of ginger will double in the next five years (Okafor, 2007). Drying is a mass transfer process consisting of the removal of water or another solvent by evaporation from a solid, semi-solid or liquid. Drying is a process that aims at increasing shelf life of a food product by reducing the moisture content of the food product (Sebiiet al., 2002). Solar food drying is a form of solar food processing which uses airflow and solar energy to dehydrate food for consumption and storage (Sebiiet al., 2002).

Removal of moisture by appropriate drying method can prevent deterioration reactions and reproduction of micro-organisms leading to spoilage of produce. Drying is very essential post-harvest preservation of agro produce; it has always been of great importance for conserving agricultural products and for extending the food shelf-life. These solar dryers and oven dryers allow for controlled drying by managing the drying parameters such as moisture content, air temperature, humidity, and air flow rate (Eze and Agbo, 2011). This study therefore investigated the effect of three pre-drying chemical treatments on the quality (proximate and microbial content) and sensory properties of dried (ambient, solar and oven ginger.

2. Materials and Methods:

Fresh and matured ginger rhizomes (Zingiber officinale) without defects were procured from Ogige main market in Nsukka L.G.A. Food preservative chemicals (citric acid, calcium oxide and sodium meta bisulphate) were obtained from the Department of Food Science and Technology laboratory, University of Nigeria, Nsukka. Other materials also used; analog hygrometer, hand gloves, weighing balance, bowls, plastic basket, trays, digital thermometer, stainless steel knife and stop clock. Fresh ginger rhizomes were washed, sorted, peeled to remove the cork skin and manually sliced into desired sizes (4 mm thickness) using a knife. The ginger slices were divided into three equal weight (each of 1.5 kg), pre-treated before solar, oven or ambient drying by dipping in three (3) food chemicals; 2% calcium oxide, 2% citric acid and 2% sodium meta bi-sulphite (2%) at 3 minutes interval and dried using solar dryer (36 h), oven dryer (28 h) and ambient (45 h) drying methods. After drying (to constant weights), the samples were weighed, packaged in high density moisture proofed polyethylene material for subsequent analysis of proximate using standard methods of AOAC (2010) and microbial analysis as described below.

2.1 Microbial Analysis

Determination of total viable count (TVC)

This was determined using the methods by Prescott et al. (2005). The sample (I g) was weighed into sterilized test tube. 9 ml of ¼ strength ringer solution was poured into the test tube and mixed thoroughly by shaking. Then one (1) ml of the sample solution was transferred into the test tube and shaken, 1 ml of the solution from test No. 1 was pipetted into second test tube containing nine (9) ml of the ringer solution, one (1) ml of the solution was transferred to the third test tube and the serial dilution continued to the test tube. Later 0.1 ml was transferred from each test tube into corresponding plate and five (5) ml of sterile nutrient agar medium was poured and mixed thoroughly by rocking the plates. The plates were incubated in an incubator upside down at 37 0C for 24 hours after which the colonies formed was counted and expressed as colony forming units per gram. The morphological characters on the agar plate was used for tentative identification were possible.

Determination of mould count

This was done according to Prescott et al. (2005). The mould was cultured on potato dextrose agar (PDA). About 65 g of PDA was dissolved in a litter of distilled water in a clean 250 ml flat bottom flask and then sterilized in an autoclave at 15 psi at 1210C for 20 min and allowed to cool in a desiccator. It was poured into a sterile petri dishes and allowed to cool and solidify at room temperature. For the serial dilution ¼ strength Ringer's tablet was dissolved in 500 ml flask, covered with cotton wool and aluminum foil, and sterilized in an autoclave along with the PDA at 1210C for 15 min. Serial dilutions was made for the test. Nine (9) ml of the diluents was transferred to each of the 5 sterile test tubes with the diluent bottles closed with cotton wool and aluminum foil. Then 2 g of the samples was mixed in the diluent bottles containing 1 ml of ringer's solution. Then 1 ml of the sample solution was transferred to no 2 and no 3 test tubes and serial dilution continued to the last test tube. Then 1 ml was taken from each of the test tube and poured in petri dished with small quantity of PDA and shaken very well to cover the bottom. The petri dishes were incubated upside down for 8 hours at 300C. The mould colonies on each plate was enumerated and calculated as colony forming unit (CFU) per gram of the sample. CFU/g = number of colonies x dilution factor.

2.2 Sensory Evaluation

The sensory qualities (colour, taste, aroma, texture, mouth feel, and aftertaste) and overall acceptability of the dried ginger samples were evaluated by 20 semi-trained panellists consisting of staff and students of University of Nigeria Nsukka. The sensory scores between the samples for each attribute was determined on a nine – point Hedonic scale, where 9 represents extremely like and 1 represents extremely dislike according to Ihekoronye and Ngoddy (1985).

2.3 Data Analysis and Experimental Design

The experimental design used was the complete randomized design (CRD) and the data obtained were analyzed using one – way analysis of variance (ANOVA). Means were separated by Ducan's multiple range test method and the level of probability was accepted at ($p < 0.05$) (Steel and Torrie, 1980).

3. Results and Discussion:

3.1 Effect of Chemical Pre-treatment on Proximate Composition of Dried Ginger Samples

The results of the proximate composition (crude fat, crude protein, ash, crude fibre, moisture and carbohydrate) are presented in Table 1. Chemical pre-treatments and drying methods significantly ($p < 0.05$) affected flour samples of dried ginger. The result shows that the moisture value (content) (MC) of fresh sample (79.6%) is higher than all dried samples. In sodium meta bisulphate treated samples, MC of oven dried sample (5.15%) is lower than solar and ambient dried samples (6.50, 6.62%). In citric acid treated samples, MC of oven dried sample (5.23%) is lower than ambient and solar dried samples (6.36, 6.52%). In calcium oxide treated samples, MC of oven dried sample (5.12%) is lower than ambient and solar dried samples (5.97, 6.24%). This is true since concentrated composition of nutrient and increased shelf-life are achieved at reduced moisture values. The calcium oxide pre-treated dried ginger shows lowest moisture values. This is could be due to salt brining which leads to dehydration of the ginger samples and also the oven high temperature applied at short time when compared to sun and solar dryer. Ash is important food constituent and inorganic residue after combustion at high temperature - prolonged time (Idowu et al., 2013). The ash content of fresh sample (3.52%) were lower than dried samples (5.04 – 5.06.5%). The protein content (PC) of fresh sample (5.58%) is lower than all dried samples. In sodium meta bisulphite treated samples, PC of oven dried sample (8.42%) is lower than solar and ambient dried samples (9.35, 9.02%). In citric acid treated samples, PC of oven dried sample (7.60%) is lower than ambient and solar dried samples (9.14, 9.02%). In calcium oxide treated samples, PC of oven dried sample (6.86%) is lower than ambient and solar dried samples (9.09, 8.87%).

The solar dried samples (sodium meta bisulphate treated) had highest value of 9.35% as a result of higher concentration without denaturation which was observed in ambient dried ginger products. The reduced crude protein values could be due to leaching out of nutrients and prolonged drying in an uncontrolled environment. The fat and fibre compositions of dried products (0.9 – 2.77%; 8.23 – 8.71%) were greater than control samples ones (0.05%; 8.01%), respectively, as result of other nutrients concentrations. Study showed that ambient dried root and tuber crops had high fat than other drying methods (Akubor and John, 2012). The reduced fat composition of the oven dried ginger products could be due to oxidation at higher temperature values. The carbohydrate content (CC) of fresh sample (13.53%) is lower than all dried samples. In sodium meta bisulphite treated samples, CC of oven dried sample (78.30%) is higher than solar and ambient dried samples (72.50, 74.25%). In citric acid treated samples, CC of oven dried sample (79.60%) is higher than ambient and solar dried samples (74.44, 73.03%). In calcium oxide treated samples, CC of oven dried sample (80.86%) is higher than ambient and solar dried samples (76.08, 74.08%).

Table 1: Proximate compositions (%) of the pre- treated dried ginger samples

Samples	Moisture	Protein	Fat	Ash	Fiber	Carbohydrate
A0	$79.6^{a}\pm0.01$	$5.58^{i}\pm0.01$	$0.05^{j}\pm0.03$	$3.52^{b}\pm0.02$	$8.01^{d}\pm0.01$	$13.53^{c}\pm0.01$
ASG	$6.50^{b}\pm0.03$	$9.35^{a}\pm0.04$	$2.77^{a}\pm0.01$	$5.04^{a}\pm0.02$	$8.71^{a}\pm0.04$	$72.50^{ab}\pm0.07$
AAG	$6.62^{c}\pm0.01$	$9.02^{d}\pm0.01$	$2.66^{b}\pm0.02$	$5.06^{a}\pm0.01$	$8.51^{b}\pm0.30$	$74.25^{ab}\pm0.28$
AOG	$5.15^{h}\pm0.04$	$8.42^{f}\pm0.03$	$1.86^{e}\pm0.01$	$5.06^{a}\pm0.01$	$8.21^{c}\pm0.17$	$78.30^{ab}\pm0.14$
BSG	$6.52^{c}\pm0.01$	$9.14^{b}\pm0.01$	$2.63^{c}\pm0.05$	$5.00^{a}\pm0.07$	$8.61^{b}\pm0.23$	$73.03^{a}\pm0.22$
BAG	$6.36^{d}\pm0.02$	$9.02^{d}\pm0.01$	$2.58^{d}\pm0.01$	$5.04^{a}\pm0.01$	$8.56^{b}\pm0.04$	$74.44^{ab}\pm0.07$
BOG	$5.23^{f}\pm0.02$	$7.60^{g}\pm0.30$	$1.26^{h}\pm0.02$	$5.05^{a}\pm0.04$	$8.25^{c}\pm0.11$	$79.60^{ab}\pm0.21$
CSG	$6.24^{e}\pm0.03$	$9.09^{c}\pm0.01$	$1.84^{f}\pm0.01$	$5.04^{a}\pm0.06$	$8.72^{a}\pm0.22$	$74.08^{ab}\pm0.20$
CAA	$5.97^{g}\pm0.01$	$8.87^{e}\pm0.02$	$1.53^{g}\pm0.05$	$5.05^{a}\pm0.01$	$8.51^{b}\pm0.21$	$76.08^{ab}\pm0.21$
COG	$5.12^{h}\pm0.02$	$6.86^{h}\pm0.01$	$0.90^{i}\pm0.03$	$5.04^{a}\pm0.02$	$8.23^{c}\pm0.54$	$80.86^{b}\pm0.51$

Results are means of duplicate ± standard deviation, means with different superscript on the same column are significantly $p < 0.05$ different.

Key: A0- fresh ginger, ASG- ginger treated with sodium meta bi-sulphate and solar dried; AOG- ginger treated with sodium meta bi-sulphate and oven dried, AAG- ginger treated with sodium meta bi-sulphate and ambient dried, BSG- ginger treated with citric acid and solar dried, BOG- ginger treated with citric acid and oven dried, BAG- ginger treated with citric acid and ambient dried, CSG- ginger treated with calcium oxide and solar dried, COG- ginger treated with calcium oxide and oven dried, CAG- ginger treated with calcium oxide and ambient dried; CHO- carbohydrate.

3.2 Effect of Chemical Pre-treatment on Microbial Load of Dried Ginger Samples

The microbial (total viable count (TVC) and mould) results of chemical pre-treated dried ginger samples are presented in Table 2.

Table 2: Microbial composition of samples

Samples	TVC (cfu/g)	Mould (cfu/g)
ASG	2.01×10^{2}	2.0 × 10
AOG	1.90×10^{2}	1.1 × 10
AAG	2.10×10^{3}	4.2× 10
BSG	2.05×10^{2}	4.0 × 10
BOG	2.00×10^{2}	3.8 × 10
BAG	2.11×10^{3}	7.0 × 10
CSG	3.23×10^{2}	5.3 × 10
COG	3.02×10^{2}	4.3 × 10
CAG	4.20×10^{3}	9.8 × 10

Results are means of duplicate ± standard deviation, means with different superscript on the same column are significantly $p < 0.05$ different.

Key: A0- fresh ginger, ASG (ginger treated with sodium meta bi-sulphate and solar dried), AOG (ginger treated with sodium meta bi-sulphate and oven dried), AAG (ginger treated with sodium meta bi-sulphate and ambient dried), BSG (ginger treated with citric acid and solar dried), BOG (ginger treated with citric acid and oven dried), BAG (ginger treated with citric acid and ambient dried), CSG (ginger treated with calcium oxide and solar dried), COG (ginger treated with calcium oxide and oven dried), CAG (ginger treated with calcium oxide and ambient dried)

Total viable count of the dried ginger

The total viable count (TVC) of sodium meta bisulphite treated oven dried sample (1.90 × 102cfu/g) was lower than solar and ambient dried samples (2.01 × 102, 2.10 × 102). The TVC (total viable count) of samples dried using ambient method had the highest values which ranged from (2.10 ×103 - 4.20 ×103 Cfu/g). This is because drying was done in an environment that is open to microbial attack, insect and pest infestation and environmental pollution. The total viable count of the samples dried using oven dryer had the lowest values ranging from (1.90 × 102 - 3.02 ×102Cfu/g). The lower microbial count of solar and oven dried samples could be due to higher temperature and faster drying rate obtained during drying.

Mould count of dried ginger

Due to lower moisture content and higher drying temperature obtained in oven drying of samples, it recorded lower mould count (1.1 ×10 - 4.3 × 10 Cfu/g) than solar and ambient dried samples. Ambient dried samples had the highest mould count (4.2 ×10 - 9.8 ×10) due to contamination from environment. Samples treated with sodium metabisulphite suppressed mould growth when compared with samples treated with citric acid and calcium oxide that had mould growth, since citric acid and calcium oxide had no effect on the mould count (Prescott et al., 2005).

3.3 Effect of Pre-treatment on Sensory Properties of Dried Ginger Samples

The sensory scores of the study are presented in the Table 3.

Table 3: Sensory scores of the dried ginger samples

Samples	Colour	Texture	Aroma	Overall acceptability
ASG	8.65^{b}±1.53	8.10^{c}±1.63	8.15^{d}±0.95	8.50^{a}±0.44
AOG	7.70^{ab}±1.02	7.80^{d}±0.44	7.70^{e}±1.89	7.60^{d}±0.60
AAG	4.45^{d}±1.05	4.90^{ab}±1.24	3.80^{bc}±1.98	3.90^{g}±1.52
BSG	7.90^{ab}±0.22	7.84^{b}±0.60	7.70^{cd}±1.67	7.85^{b}±0.44
BOG	7.95^{ab}±0.91	7.35^{d}±0.76	7.05^{ab}±0.93	7.40^{e}±0.64
BAG	3.15^{e}±0.87	3.65^{b}±0.59	3.30^{bc}±1.00	3.15^{h}±1.09
CSG	7.75^{ab}±0.00	7.05^{c}±1.09	7.55^{a}±0.44	7.65^{c}±0.88
COG	7.40^{a}±0.51	6.95^{c}±0.41	6.15^{f}±1.39	6.20^{f}±1.36
CAG	1.45^{c}±0.81	1.20^{a}±.0.44	2.25^{ab}±0.88	2.50^{i}±0.59

Values are mean ± standard deviation of triplicate readings. Mean values on the same column with different superscripts are significantly ($p < 0.05$) different.

Key: ASG (ginger treated with sodium meta bi-sulphate and solar dried), AOG (ginger treated with sodium meta bi-sulphate and oven dried), AAG (ginger treated with sodium meta bi-sulphate and ambient dried), BSG (ginger treated with citric acid and solar dried), BOG (ginger treated with citric acid and oven dried), BAG (ginger treated with citric acid and ambient dried), CSG (ginger treated with calcium oxide and solar dried), COG (ginger treated with calcium oxide and oven dried), CAG (ginger treated with calcium oxide and ambient dried)

Colour

The sensory score for colour ranged from 3.45 - 8.45. The samples ASG, AOG and AAG (treated with sodium metabisulphate) had the highest (8.86, 7.90 and 7.75) score and samples CSG, COG and CAG (treated with calcium oxide) had the lowest (4.45, 3.15 and 1.45) score. There was a significant $p < 0.05$ difference between those treated with different chemicals and those dried with different drying methods. The sample dried using solar and oven dryer were preferred over samples dried using ambient drying method due to discoloration as a result of long exposure to direct ultra violet rays.

Texture

The texture of the dried ginger indicates how smooth, coarse, rough and gritty the samples are. Texture score ranged as follows; from 4.9 – 7.8 in solar dried samples, from 3.65 – 7.84 in oven dried samples and from 1.2 – 7.05 in ambient dried samples. Solar and oven dried samples (ASG, AOG, BSG, BOG, CSG and COG) having the highest (8.10, 7.80, 7.84, 7.35, 7.05 and 6.95) values, respectively were preferred over ambient samples (AAG, BAG and CAG) having the lowest (4.90, 3.65 and 1.20) values by the panelist due to their poor texture.

Aroma

The aroma of the dried ginger indicates the pungency of the scent, the sensory scores for aroma ranged from 4.30 – 8.23 with samples ASG, AOG, BSG, BOG, CSG and COG (dried using solar and oven dryer) having the highest (8.15, 7.70, 7.70, 7.05, 7.55 and 6.15) values and samples AAG, BAG and CAG (dried using ambient drying) having the lowest (3.80, 3.30 and 2.25) values. The judges preferred samples dried with solar dryer and oven dryer to samples dried using ambient drying method. The direct ultra violet rays on the ambient ginger dried contributed to this loss according to (Nambudri and Marthew, 2015).

Overall acceptability

There were significant ($p < 0.05$) differences between the fresh samples and the dried samples, between the treated samples using the same drying methods and between the different drying methods. The panel of judges preferred sample ASG and BSG (ginger treated with sodium metabisulphate and citric acid, respectively and dried using solar dryer) due to their acceptable yellow colour, smooth texture and pungent aroma, over ambient dried samples.

Conclusion

The fresh ginger samples (pre-treated and control) were processed and dried with sun, solar and oven drying methods. Higher temperature applied in ginger dehydration denatures its protein. In the conversion of these samples to flour, the results obtained from this research shows that the pre-treatments of ginger with sodium meta bisulphite and citric acid prior to drying had a significant effect on their proximate compositions. The data obtained shows that chemical pre-treatments prior to drying have positive impacts on the sensory characteristics of the ginger. Attributes of ginger quality such as aroma and colour could also been altered via losses during drying at high temperature. The solar and oven dried samples were preferred over ambient dried ones. Solar and oven drying appeared to be best safer option in preservation of ginger since their microbial qualities were within acceptable limits than ambient drying method. Application of solar drying method in ginger preservation is recommended as the best option so as to produce microbiologically and hygienically safer dried product.

References

Akubor, I. and John, I. (2012). Quality evaluation and cake making potential of sun and oven dried carrot fruit. International Journal of Biosciences, 10(2):19-27.

AOAC. (2010). Official methods of analysis. Association of Official Analytical Chemists. (18th Edition). Gaithersburg, USA.

Bombenet, J. L., Bruin, S., Thijssen, H. A. and Merson, R. L. (2013). Aroma recovery and retention in concentration and drying. Advances in Food Research, 20: 1-111.

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.

Fumen, E. A., Yiljep, Y. D. and Ajisegiri, E. S. (2003). Survey of ginger processing and drying methods in Nigeria. A case of Southern Kaduna of Kaduna State. Fourth International Conference and 25th AGM of the Nigerian Institution of Agricultural Engineers, Damaturu, Nigeria, September 8th – 12th.

Idowu, O., Olaoye, O., Sogotemi, C. and Ajayi, B. (2013). Quality assessment of flours and amala produced from three varieties of sweet potato Ipomea batatas. International Journal of Food and Nutritional Sciences, 2(4): 2320-7876.

Ihekoronye, A. I. and Ngoddy, P. O. (1985). Integrated Food Science and Technology for the Tropics. 1st Edition, Macmillan Publishers.

Nambudri, E. S. and Marthew, A. K. (2015). Quantitative determination of the pungent principle in ginger. Flavor, 6: 135 - 137.

Okafor, G. I. (2007). Effect of pricking and sieving on Ginger (Zingiber officinale Rosce) colour and powder. Nigerian Food Journal, 25(1): 156-160.

Prescott, L. M., Harley, J. P. and Klein, O. A. (2005). Microbial Nutrition, types of media. In: Microbiology, 6th Edition, McGraw Hill Publishers, New York. pp. 95 – 105.

Sebii, A. A., Abdoul–Enein, S., Ramadan, M. R. I. and El-Gohary, H. G. (2002). Experimental investigation of an indirect type natural convection solar dryer, Energy Conversion and Management, 43: 225-226.

Steel, R. G. D. and Torrie, J. H. (1980). Principle and procedure of statistics. McGraw Hill, Tropics. Macmillan Publishers Ltd., London. pp. 106 - 112.