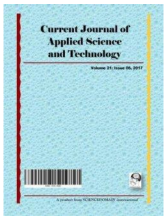

Current Journal of Applied Science and Technology

26(6): 1-10, 2018; Article no.CJAST.38796
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Effects of Drying Methods on the Chemical Properties of Okra (*Abelmoschus esculentus* L. Moench) Slices

J. B. Hussein[1*], J. O. Y. Ilesanmi[1], K. B. Filli[2] and M. S. Sanusi[3]

[1]Department of Food Science and Technology, Modibbo Adama University of Technology, Yola, P. M. B. 2076, Yola, Adamawa State, Nigeria.
[2]Product Design and Perception, Agrifood and Bioscience - Research Institutes of Sweden (RISE) Gothenburg, Sweden.
[3]Department of Food Technology, Faculty of Technology, University of Ibadan, Ibadan, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Author JBH designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors JOYI and KBF managed the analyses of the study and the literature searches. Author MSS performed the statistical analysis. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2018/38796
Editor(s):
(1) Ming-Chih Shih, Professor, Department of Health and Nutrition Science, Chinese Culture University, Taiwan.
Reviewers:
(1) F. O. Adebayo, Nassarawa State University, Nigeria.
(2) Sachidananda Swain, ICAR-CIARI, India.
(3) Sabina Lachowicz, Vegetable and Plant Nutraceutical Technology, Wroclaw University of Environmental and Life Sciences, Poland.
(4) Ouoba Kondia Honoré, UFR-Sciences and Technology, Polytechnic University of Bobo, Burkina Faso.
Complete Peer review History: http://www.sciencedomain.org/review-history/24147

Original Research Article

Received 7th November 2017
Accepted 15th January 2018
Published 14th April 2018

ABSTRACT

Okra (*Abelmoschus esculentus*) samples were subjected to three different drying methods using solar, sun and oven. Chemical and sensory properties of the dried okra samples were investigated using fresh okra as a control. Natural open sun drying took about $19^{1}/_{2}$ hours to dry the okra to a constant moisture content of 12.67% (w/b), solar dryer took 12 hours to dry to 12.50% (w/b) and hot air oven took about $10^{1}/_{2}$ hour to dry to 5.50% (w/b). The results of chemical properties showed that the fresh okra contained 75.67% moisture, 11.99 % crude protein, 0.34% crude fat, 1.03% crude ash, 0.50% crude fiber, 10.47% carbohydrate, 92.90 Kcal energy value, 12.83 cP viscosity and

**Corresponding author: E-mail: husseinjelilibabatunde@yahoo.com, jbhussein01@mautech.edu.ng;*

26.04 mg/100 g vitamin 'C'. The open sun dried okra contained 21.93% crude protein, 2.56% crude fat, 9.33% crude ash, 8.05% crude fiber, 45.46% carbohydrate, 292.60 Kcal energy value, 13.10 cP viscosity and 17.14 mg/100 g vitamin 'C'. Solar dried okra contained 29.40% crude protein, 4.91 % crude fat, 10.12% crude ash, 8.71% crude fiber 34.36% carbohydrate, 299.23 Kcal energy value, 15.47 cP viscosity and 19.21 mg/100 g vitamin 'C'. Oven dried okra contained 17.97% crude protein, 2.20% crude fat, 9.23% crude ash, 6.12% crude fiber, 58.98% carbohydrate, 333.60 Kcal energy value, 21.13 cP viscosity and 14.08 mg/100 g vitamin 'C'. The above results showed that the drying methods used have a significant effect ($p<0.05$) on the physicochemical properties of the dried okra. The nutritional and sensory quality of the solar dried okra is superior to open sun and oven dried okra. It was concluded that better quality shelf stable dried okra can be obtained by solar drying method.

Keywords: Okra; drying method; chemical properties; sensory quality.

1. INTRODUCTION

Okra (*Abelmoschus esculentus* L. Moench) is a semi-woody, fibrous and herbaceous annual plant which originated probably from East Africa and today is widely distributed in the tropics, subtropics and warmer portions of the temperate region [1]. It is a vegetable crop that belongs to the genus *Abelmoschu*s, family *Malvaceae* and has two main species: *Abelmoschus esculentus* (L.) Moench and *Abelmoschus caillei* (A. Chev.) Stevels [2]. *Abelmoschus esculentus* (L.) Moench is the widespread species in tropical, subtropical and warm temperate regions while *Abelmoschus caillei* (A. Chev.) Stevels is restricted to the humid and perhumid climates of Africa [3]. Okra is mainly grown for its tender green pods and leaves, which are cooked and commonly consumed as boiled vegetables [4]. Its total commercial production in the world was estimated at 4.8 million tons, with India and Nigeria being the predominant producers [5]. Other minor producers include Pakistan, Ghana, Egypt, Ethiopia, Iran, Iraq, Turkey, Brazil, Guyana, Japan and USA.

Okra is known by many local names in different parts of the world. It is called Lady's finger in England, Gumbo in the United State of America, Guino-gombo in Spanish, Guibeiro in Portuguese and Bhindi in India [6]. Also in Nigeria, it is known as *Ila* in "Yoruba", *Kubewa* in "Hausa" and *Okwale* in "Igbo" language. Bamire and Oke [7] reported that there are two distinct seasons for okra farming in Nigeria, the peak and the lean seasons. During the lean season, okra is produced in low quantities, scarce and expensive to get. While in the peak season, it is produced in large quantities much more than what the local populace can consume.

The cultivation and production of okra have been widely practised due to its nutritional importance and medicinal value. The consumption of this perishable fruits forms an essential part of nutrition through the provision of nutrients for growth and good health. Okra is a good source of carbohydrate, protein, dietary fibre, calcium, magnesium, potassium, vitamins A and C [8,9]. Okra contains glycans, a substance responsible for the viscosity of aqueous suspension [10] and the stringy, gum-like consistency that is desired in good quality soups [11]. It is also an excellent source of iodine, which is useful for the treatment of goiter. The powdered root of okra is consumed along with sugar as a treatment for a leucorrhoea backache [12]. Okra acts as a tonic for both man and woman and enables them to increase their vitality and vigour. Mucilage from the stem and roots is used for clarifying sugarcane juice. Fully ripened fruits and stem containing crude fibre are used in the paper industry. Okra gum obtained from seedpods of *Hibiscus esculentus* is an anionic polysaccharide, which can be used as flocculant for removal of solid wastes from tannery effluent [12].

The essential and nonessential amino acids that okra contains are comparable to that of soybean [13]. Thus, it plays a vital role in the human diet. Audu et al. [13] also reported that okra has several health benefits, as it is rich in vitamin A, thiamin, vitamin B, vitamin C, folic acid, riboflavin, calcium, zinc and dietary fiber. The mucilage and fiber found in okra help adjust blood sugar by regulating its absorption in the small intestine [13]. Okra is an excellent laxative treats irritable bowels, heals ulcers and sooths the gastrointestinal track. Protein and oil contained in the seeds of okra serve as the source of first-rate vegetable protein. It is enriched with amino acids of the likes of tryptophan, cysteine and other sulfur amino acids [13]. Okra has also been recognized as the most affordable and accessible sources of micronutrient, which is increasingly regarded as a catalyst for rural development and as a means of increasing and generating foreign exchange in Africa [14,15].

However, in spite of all these enormous benefits, farmers, marketers, and consumers encounter several challenges regarding the keeping of the fresh okra fruit. Okra has poor shelf life due to the quick degeneration and decomposition of it after harvest. Thus, adequate processing, preservation, marketing and utilization of okra are necessary to arrest the wastage being experienced during the peak season. Drying process offer an alternative way of using okra thus, preventing the huge post-harvest losses and make them available in the offseason at comparatively lesser cost [16]. It is the most efficient, reliable and practically feasible methods of postharvest preservation of okra and other highly-perishable fruits and vegetables [16,17]. It also helped to develop, promote and stabilize the chain of okra powder production. Sun drying of agricultural products is the traditional method employed in most of the developing countries because it offers a cheap method of drying but often results to inferior quality of products due to its dependence of weather conditions [16,17]. On the other hand, solar energy drying is an alternative which offers several advantages over the traditional method and it has been developed for various agricultural products. It improves product qualities, makes the process more efficient by saves energy and time, and protects the environment [16]. Hot-air drying is one of the most frequently used operations for food dehydration [18,19]. However, drying can accelerate some reactions that can adversely affect the product quality too [20,21]. Also it alters other physical, biological and chemical properties of foods [21,22]. Thus, this study aimed to investigate into the effects of open sun drying, solar drying and oven drying on the chemical composition and wholesomeness of the Okra.

2. MATERIALS AND METHODS

2.1 Sample Preparation

Okra was obtained from Jimeta Modern Market Yola, Adamawa State, Nigeria. The drying experiment was conducted in March to April 2016 when the ambient temperature was approximately 27°C at 7.00 am. The Okra samples were washed in clean water and pretreated in boiling water for 30 seconds, and the water drained. The samples were then divided into three portions, each portion was sliced manually into approximately 4 mm thick. The first portion of the sliced okra 2 kg was spread in a single layer on a two different wire meshes (1 kg on each wire mesh) and sun-dried until constant moisture content was achieved at an average atmospheric day temperature 40 – 45°C for about 10 hours daily. The second portion 2 kg was dried in the constructed hybrid photovoltaic solar dryer [23] using solar collector as the heating source alone at temperature of about 40 – 45°C for about 10 hours daily. While the residual quantity 2 kg was dried in a hot air oven (Model: TO008GA-34, AKAI-TOKOYO, Japan) at 40 – 45°C until constant weight was achieved.

2.2 Determination of Chemical Composition of Fresh and Dried Okra

Samples of fresh and dried Okra were analyzed for the following parameters, moisture, protein, fat, ash, fibre, carbohydrate, energy value (Kcal), Viscosity (cP) and Vitamin C (mg/100 g). The moisture content was determined according to the method of AOAC [24]. The Samples were dried at 105°C for 4 hours using the preset oven (Fisher Scientific Isotemp Oven, model 655F, Chicago, USA). The method described by AOAC [24] was employed for ash content determination. The crucibles containing the pre-weighed samples were placed in a heated furnace (Fisher Isotemp Muffle Furnace, model 186A, USA) at 600°C for 6 hours after which they were cooled to room temperature in desiccators and weighed. The protein content (% nitrogen x 6.25) and fat content (1 g was extracted for ether extract determination using diethyl ether at 64°C as solvent) were determined according to the method of AOAC [24]. The carbohydrate content was determined by difference between 100 and total sum of the percentage of moisture, protein, fat, fibre and ash [25]. Energy values were calculated using Atwater factors of 4, 4 and 9 Kcal for protein, carbohydrate and fat respectively. A rotational viscometer (Model: Visco elite-R, V4002) was used to determine the viscosity. Vitamin C was determined using the AOAC [26] official titrimetry method.

2.3 Sensory Evaluation of Dried Okra

Quantitative descriptive analysis was adopted for sensory attribute determination. Twenty (20) semi-trained panelists who were familiar with dried okra were selected at random from Department of Food Science and Technology, Modibbo Adama University of Technology, Yola, Nigeria. Each coded samples were rated from 1 to 9 (1 and 9 for extremely like and extremely dislike, respectively). Assessed quality attributes include: appearance, aroma, texture, brittleness and overall acceptability.

2.4. Statistical Analysis

All experiments were performed in triplicate, and the results were expressed as means ± standard error (SE). Analysis of variance (ANOVA) was carried out to determine any significant differences in measurements using the SPSS statistical software (SPSS 20.0 for Windows; SPSS Inc., Chicago, IL, USA) and considering the confidence level of 95%. The significance of the difference between the means was determined using the Duncan's Multiple Range Test, and the differences were considered to be significant at $p< 0.05$ [21].

3. RESULTS AND DISCUSSION

3.1 Drying Curves

The comparison of drying curves for okra in the hot-air oven, solar dryer and natural open sun drying are shown in Fig. 1. The drying by these methods followed a falling rate period throughout. That is the drying rate during this period is mostly dependent on the rate of heat transfer to the material being dried. The initial moisture content of the fresh okra was determined in the laboratory using AOAC (2004) and 75.67 g water per 100 g slices moisture content was obtained. The natural open sun drying took about 19.50 hours to dry to constant moisture content of 12.67 % (w/b) while the drying inside the solar dryer took 12 hours to dry to constant moisture content of 12.50 % (w/b) and hot air oven took about 10.50 hours to dry to constant moisture content of 5.50 % (w/b). The result shows for our drying conditions that, oven drying method required shorter drying time when compared to solar and open sun drying methods, this behavior is expected. The solar drying method required shorter drying time when compared to open sun drying method. In other words, drying time was reduced by about 12.50 % of the total drying time spent in oven dryer when compared to solar drying, 46.15 % total drying time was reduced for oven drying when compared with open sun drying method and 38.46 % for solar dryer when compared with open sun drying. These variations in drying times were observed to be due to consistency and uniform circulation of heated air in the oven drying method when compared to others. Similar trend were observed by Bhosale and Arya [27], in cabbage, cluster bean, fenugreek, spinach and okra; Wankhade, Sapkal and Sapkal [28] in okra; Kouassi, Massara, Monde, Tiahou, Sess and Vama [29] in two varieties of okra dried via sun and electric drying and Hussein et al. [16] in tomato dried by hybrid solar drying method.

3.2 Effect of Different Drying Method on the Chemical Compositions of Fresh and Dried Okra

Table 1 shows the Chemical Properties of Fresh and Dried Okra. The result showed that the drying methods used have a significant effect ($p<0.05$) on the Chemical Composition of Okra. The moisture content of fresh Okra (FRO) was 75.67%, open sun-dried Okra (OSD) was 12.67%, solar dried (SLD) was 12.50% and hot air oven dried (OVD) was 5.50%. There is no significantly ($p > 0.05$) different between OSD and SLD samples. The results indicated that much moisture was removed in OVD sample compared to OSD and SLD samples. This implies that the product will be stable and less susceptible to microbial attack. These results is in agreement with the findings of Audu et al. [13] who worked on effect of processing methods on selected physicochemical properties of okra. Generally, during drying, water at the surface of the substance evaporates and water in the inner part migrates to the surface to get evaporated [30]. The ease of this migration depends on the porosity of the substance and the surface area available. Also high temperature, high wind speed and low relative humidity enhance quick drying of food items [30]. These factors were observed for high drying rate and lower drying time in the hot air oven drying method.

Ukegbu and Okereke [31] reported that moisture content of a food is very important on nutrient density and shelf-life of that particular food. Thus, reduction of moisture contents of any food leads to an increase in the concentration of nutrients [32] and food prepared from dried leafy

Table 1. Chemical properties of fresh and dried okra

Samples	Moisture (%)	Crude protein (%)	Crude fat (%)	Ash (%)	Crude fibre (%)	CHO (%)	Energy value (Kcal)	Viscosity (cP)	Vitamin C (mg/100 g)
FRO	75.67 ± 0.92[a]	11.99 ± 0.33[c]	0.34 ± 0.10[d]	1.03 ± 0.06[c]	0.50 ± 0.08[d]	10.47 ± 0.13[d]	92.90 ± 0.21[c]	12.83 ± 2.48[b]	26.04 ± 0.92[a]
OSD	12.67 ± 0.67[b]	21.93 ± 0.90[b]	2.56 ± 0.24[b]	9.33 ± 0.09[b]	8.05 ± 0.09[b]	45.46 ± 0.13[b]	292.60 ± 0.11[b]	13.10 ± 1.70[b]	17.14 ± 0.35[bc]
SLD	12.50 ± 0.26[b]	29.40 ± 0.62[a]	4.91 ± 0.10[a]	10.12 ± 0.07[a]	8.71 ± 0.07[a]	34.36 ± 0.09[c]	299.23 ± 0.13[b]	15.47 ± 1.77[ab]	19.21 ± 0.12[b]
OVD	5.50 ± 0.58[c]	17.97 ± 0.53[b]	2.20 ± 0.12[c]	9.23 ± 0.12[b]	6.12 ± 0.12[c]	58.98 ± 0.12[a]	333.60 ± 0.23[a]	21.13 ± 1.89[a]	14.08 ± 0.21[c]

Values are means of triplicate ±SE, Values in the same column bearing different superscripts are significantly different ($p<0.05$)
Key: FRO = Fresh Okra
OSD = Open Sun Dried
SD = Solar Dried
OVD = Hot Air Oven Dried

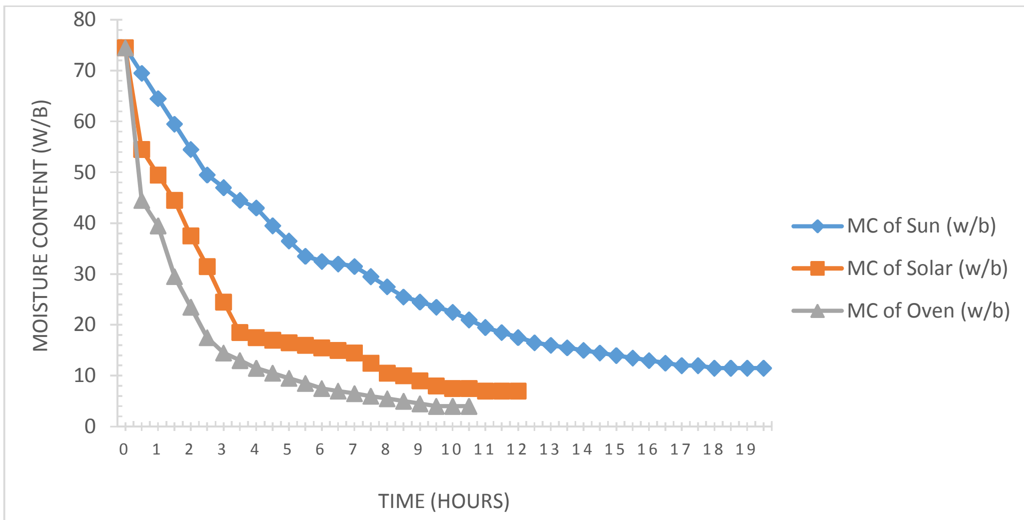

Fig. 1. The comparison of okra's drying curves in the oven, solar and open sun drying methods

vegetables has more keeping quality than the fresh one [33,34]. Kolawale, Kayode and Aina [35] reported that dried food substances, especially vegetable crops, with high moisture content will favour the growth of microorganisms at a high growth rate, and moisture content of less than 15% is said to promote enzymatic reactions and interactions of other constituents of the dried product leading to loss of vitamins [36]. Hussein [37] also reported that to process tomatoes into an intermediate moisture food product, the final moisture content should be lower than 15% to maintain dried products in a stable and low water activity state. The moisture content of the three drying methods used in this study was within the acceptable moisture level for dried vegetables.

The crude protein content of FRO was 11.99%, OSD was 21.93%, SLD was 29.40 % and OVD was 17.97 %. This result showed that the protein content of SLD Okra is significantly ($p < 0.05$) higher than FRO, OSD and OVD samples. But there is no significant ($p > 0.05$) different between OSD and SLD samples. The result disagrees with Elegbede [38] findings. He reported an increase in protein content of sun-dried vegetables compared to solar dried samples and it was observed to be due to loss of moisture which in turn has an influence on dry matter. The reduction in protein content of OSD sample compared to SLD in this study was observed to be due to prolong time of drying and that of OVD was excessive heat involved which could lead to the destruction of the protein cells. The changes in protein content might also be related to non-enzymatic browning reactions which were found to be more in the sun dried samples [39].

The fat content of FRO was 0.34%, which is significantly ($p < 0.05$) different from the dried samples. The fat content of the dried okra ranged from 2.20% to 4.91%, with the solar drying method having the highest value and open sun drying method had the least value. This increase was observed to be due to high drying rate in a short time and increase in the concentration of okra. This high drying rate for a short time also prevented melting of the fat thereby increasing their values. Similar results were reported by Audu et al. [13] for dried Okra. The ash content of the FRO was 1.03%, and that of the dried okra were 9.33% for OSD, 10.12% for SLD and 9.23% for OVD. The higher ash value of SLD samples compared to others is similar to that reported by Onwuka, Nwabara, Nwokedi, Echendu, Asumugha and Igboekwe [40] for dried Okra, Ukegbu and Okereke [31] for dried Okra and Hussein and Filli [30] for dried tomato. Ukegbu and Okereke [31] reported that ash content gives an idea about the mineral composition of food. The value of crude fibre in FRO was 0.50%, OSD was 8.05%, SD was 8.71% and OVD was 6.12%. This indicates that SLD okra contains more fiber than the OVD, OSD and FRO. Similar results were reported by Ukegbu and Okereke [31] for dried okra and Hussein and Filli [30] for dried tomato. Fiber is useful for maintaining bulk, motility and increasing intestinal tract. It is also necessary for the healthy condition, curing of nutritional disorders and food digestion [31]. The ash and crude fiber of these dried samples corroborate the finding of Adetuyi, Osagie and Adekunle [41] (7.19 to 9.63% for ash and 10.15 to 11.63% for crude fiber).

The carbohydrate contents of the FRO was 11.15%. The carbohydrate contents of the dried okra ranged from 45.46% to 58.98%. These results showed that most of the dry matter in okra is carbohydrates and okra in their fresh state have low carbohydrate. However, after drying, the carbohydrate content increased. The energy value of FRO was 92.90 Kcal, which is significantly ($p<0.05$) different from the dried samples. The fat content of the dried okra ranged from 292.60 Kcal to 333.60 Kcal, with the solar drying method having the highest value and open sun drying method had the least value. Ukegbu and Okereke [31] reported that vegetables are not good sources of dietary energy, and this may be because of the high water content, high crude fiber and low-fat levels. Thus, they are usually supplemented with other foods such as cereals, tubers, roots and legumes.

The viscosity of the FRO was 12.83 cP, which was not significantly ($p>0.05$) different from the OSD (13.10 cP) and SLD (15.47 cP) samples. The OVD sample having the highest value (21.13 cP). It was not significantly ($p>0.05$) different from SLD but significantly ($p<0.05$) different from FRO and OSD. From this result, it was observed that increase temperature and prolong time of drying could lead to reduction in viscosity strength, due to binding of the water molecule with substance in the okra. The vitamin C content of the FRO was 26.04 mg/100 g, which was significantly ($p<0.05$) different from the dried samples. The OSD Okra was 14.08 mg/100 g, SLD was 19.21 mg/100 g and OVD was 17.14 mg/100 g. Solar dried okra slices showed a higher retention of vitamin C than OSD and OVD Okra. Also OSD okra slices showed a higher retention of vitamin C than OVD okra. This variation in retention of vitamin C was observed to be due to variations in temperature, period of drying, time of exposure to direct sunlight and the presence of air. This reduction may also be due to leaching of the vitamin C being water soluble and oxidation due to longer period of drying Hussein et al. [21]. Similar results for ascorbic acid contents have been reported by Osunde and Musa-Makama [42] in okra, Tomato and Sweet pepper. Based on the statistical analysis of variance used, it was observed that the drying method, the drying temperature, size and nature of the test sample and the time of drying all had significant effects on the chemical properties of fresh and dried okra.

3.3 Effect of Drying Methods on the Sensory Evaluation of Dried Okra

The results of sensory evaluation from twenty member trained panel of judges that are familiar to sensory attribute of dried okra was presented in Fig. 2. The degree of difference among the samples were statistically significant at 95 % probability level ($p<0.05$). From the spider chart in Fig. 2, there was high variation in test samples. In terms of appearance, solar dried was rated the highest (8.80) follow by open sun-dried okra (7.23) and hot air oven dried okra (6.69). The solar dried okra significantly ($p<0.05$) different from the open sun and oven-dried samples. It was ranked highest, having a bright green appearance when compared with the other samples. This was followed by okra dried by the open sun and the oven-dried samples. There was no significance ($p>0.05$) difference between open sun and solar dried samples. However, oven dried okra was ranked lowest value in appearance due to its dull appearance and this was observed to be due to high drying temperature in oven compared to others. Similar results were reported by Audu et al. [13] for okra and Hussein et al. [16] for tomatoes. In terms of aroma, solar okra was rated the highest (7.75) follow by oven-dried okra (6.88) and open sun-dried okra (5.99). This shows that the aroma of solar dried okra was more preferable than that of oven dried okra and that of oven dried okra was more preferable than open sun-dried okra. The same trend was obtained for brittleness, texture and overall acceptability.

The brittleness and textural attributes of dried okra play a significant role in consumer appeal, buying decisions and eventual consumption. The brittleness indicates the level of dryness of the samples that is the extent of moisture removal. The brittleness of the samples also improved the textural attributes of the samples which are an

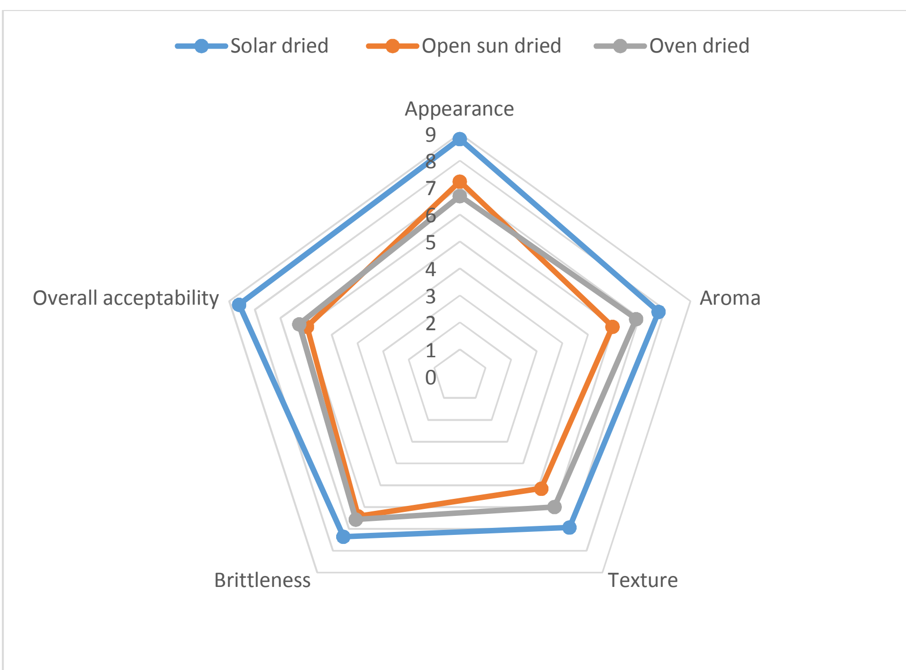

Fig. 2. Sensory evaluation of dried Okra

indication of whether the okra is hard, woody or tender. Thus, from the results obtained from twenty member panels, it could be concluded that the sensory quality of the dried okra produced from solar drying method is superior to the sensory quality of other drying method examined.

4. CONCLUSION

The study concluded that good quality shelf stable dried okra slices could be produced using solar drying method. The time required to dry the okra slices was comparatively lower in hot air oven drying when compared to solar and open sun drying. The drying method had an effect on the chemical content of the okra (protein, ash, fat, crude fiber and carbohydrate). The results for organoleptic properties showed that the dried okra produced by solar drying method was superior to hot air oven and open sun-dried okra slices at 95 percent probability level. The study has therefore provided information useful in drying process design for okra which will assist in reducing postharvest losses of okra.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Nosiru MO, Banjo JOS, Adedeji TO. Determinants of improved productivity of Okra (*Abelmoschus esculentus*) by Farmers in lowland areas of Ogun State, Nigeria American-Eurasian Journal of Agriculture and Environmental Science. 2012;12(12):1572-1578.
2. Sharma BR. Genetic improvement of vegetable crops. Kalloo G, Bergh BO, editors. Oxford and New York: Pergamon press; 1993.
3. Siemonsma JS, Kouamé C. *Abelmoschus esculentus* (L.) Moench. [Internet] Record from PROTA4U Wageningen, Netherlands: PROTA (Plant Resources of Tropical Africa / Ressources végétales de l'Afrique tropicale); 2004.
4. Chattopadhyay A, Dutta S, Chatterjee S. Seed yield and quality of okra as influenced by sowing dates African Journal of Biotechnology. 2011;10(28):5461-5467.
5. Gulsen OS, Karagul S, Abak K. Diversity and relationships among Turkish germplasm by SRAP and Phenotypic Marker Polymorphism Biologia. 2007;62:41-45.
6. Ndunguru J, Rajabu AC. Effect of Okra mosaic virus disease on the above-ground morphological yield components of okra in Tanzania. Scientia Horticulturae. 2004;99:225-235.
7. Bamire AS, Oke JT. Profitability of vegetable farming under rainy and dry season production in Southwestern Nigeria. Journal of Vegetable Crop Production. 2003;9:11–18.
8. Adom KK, Dzogbefia VP, Ellis WO, Simpson BK. Solar drying of okra-effects of selected package materials on storage stability. Food Research International. 1996;29(7):589–593.
9. Sobukola O. Effect of pre-treatment on the drying characteristics and kinetics of okra (*Abelmoschus esculetus* (L.) Moench) slices. International Journal of Food Engineering. 2009;5(2):9:1-22.
10. Owoeye AL, Lauric MC, Allagheny NN, Onyezili FN. Chemical and physical parameters affecting the viscosity of the mixed okra and tomato homogenate. Journal of Science and Agriculture. 1990;53:283–286.
11. Falade KO, Omojola BS. Effect of processing methods on physical, chemical, rheological, and sensory properties of okra (*Abelmoschus esculentus*). Food Bioprocess Technology. 2010;3:387–394.
12. Agarwal M, Rajani S, Mishra A, Rai JSP. Utilization of okra gum for treatment of tannery effluent. International Journal of Polymeric Materials, 2003;52(11): 1049–1057.
13. Audu J, Anyebe SB, Kwaya PV. Effect of processing methods on selected physicochemical properties of okra (*Abelmoschus esculentus*). International Journal of Engineering Technology and Computer Research (IJETCR). 2015;3(5):118–125.
14. AVRDC, editor 11th Regional training course on vegetable crop production and Research 2004 4th July – 4th November, Tanzama; 2004.
15. Ngbede SO, Ibekwe HN, Okpara SC, Onyegbule UN, Adejumo L. An overview of okra production, processing, marketing, utilization and constraints in Ayaragu in Ivo local government area of Ebonyi State, Nigeria. Greener Journal of Agricultural Sciences. 2014;4(4):136-143.

16. Hussein JB, Usman MA, Filli KB. Effect of hybrid solar drying method on the functional and sensory properties of tomato. American Journal of Food Science and Technology. 2016;4(5):141-148.
17. Amer BMA, Hossain MA, Gottschalk K. Design and performance evaluation of a new hybrid solar dryer for banana. Energy Conversion and Management. 2010;51: 813-820.
18. Krokida MK, Maroulis ZB. Effect of microwave drying on some quality properties of dehydrated products drying Technology. 1999;17:449-466.
19. Youssef KM, Mokhtar SM. Effect of drying methods on the antioxidant capacity, color and phytochemicals of *Portulaca oleracea* L. leaves. Journal of Nutrition and Food Sciences. 2014;4(6):322.
20. Akanbi CT, Oludemi FO. Effect of processing and packaging on the lycopene content of tomato products. International Journal of Food Properties. 2004;7: 139-152.
21. Hussein JB, Sanusi MS, Filli KB. Evaluation of drying methods on the content of some bio-actives (lycopene,-carotene and ascorbic acid) of tomato slices. African Journal of Food Science. 2016;10(12):359-367.
22. Demirhan E, Özbek B. Drying kinetics and effective moisture diffusivity of purslane undergoing microwave heat treatment. Korean Journal of Chemical Engineering. 2010;27:1377-1383.
23. Hussein JB, Hassan MA, Kareem SA, Filli KB. Design, construction and testing of a hybrid photovoltaic (PV) solar dryer. International Journal of Engineering Research and Science. 2017;3(5):1-14.
24. AOAC. Official methods of analysis, Association of Official Analytical Chemist Washington D.C.; 2004.
25. AOAC. Official method of analysis, Association of Official Analytical Chemists. 14th ed: Washington D.C.; 1990.
26. AOAC. Official method of analysis. Association of Official Analytical Chemist. Washington D.C.; 2010.
27. Bhosale BS, Arya AB. Effect of different modes of drying on moisture content and drying time of the selected vegetables. The Indian Journal of Nutrition and Dietetics. 2004;41:293.
28. Wankhade PK, Sapkal RS, Sapkal VS, editors. Drying characteristics of okra slices using different drying methods by comparative evaluation proceedings of the world congress on engineering and computer science; 2012 October 24-26, 2012; San Francisco, USA.
29. Kouassi JB, Massara C, Monde AA, Tiahou GG, Sess DE, Vama ET. Comparative study of proximate chemical composition of two varieties of okra dried by two methods: Sun and electric drying. American Journal of BioScience. 2013;1(4):74–79.
30. Hussein JB, Filli KB, editors. Effect of different drying methods on physicochemical properties of tomato (*Lycopersicon esculentum* Mill.) slices Proceedings of the 39th conference and annual general meeting of Nigerian Institute of Food Science and Technology; 2015; Owerri, Nigeria: Nigerian Institute of Food Science and Technology.
31. Ukegbu PO, Okereke CJ. Effect of solar and sun drying methods on the nutrient composition and microbial load in selected vegetables, african spinach (*Amaranthus hybridus*), fluted pumpkin (*Telferia occidentalis*), and okra (*Hibiscus esculentus*). Sky Journal of Food Science. 2013;2(5):35–40.
32. Morris A, Barnett A, Burrows O. Effect of processing on nutrient content of foods: A Handbook of vegetables and vegetable processing. Asian Journal of Biochemistry. 2004;37(3):160–164.
33. Achanta S, Okos MR. Quality changes during drying of food polymers. In: Mujumdar AS, Suvachittanont S, editors. Development in Drying. 2: Food dehydration, Kasetsart University Press; 2000;195–209.
34. Chou SK, Chua KJ. New hybrid drying technologies for heat sensitive foodstuffs. Trends in Food Science and Technology. 2001;12(10):359-369.
35. Kolawale OM, Kayode RMO, Aina J. Effect of solar drying on the proximate and microbial composition of *Abelmoschuus escuulentus.* Journal of Agricultural Science. 2010;2:214–224.
36. Fellows PS. Food processing technology: Principles and practice. New York: Wood Head Rebleing Ltd; 1997.
37. Hussein JB. Design, Construction and testing of a hybrid dryer using photovoltaic solar panel. Yola: Modibbo Adama University of Technology, Yola; 2016.

38. Elegbede JA. Legumes. Nutritional quality of plant foods. In: Osagie AU, Eka QU, editors. Post Harvest Research Unit; 1998.
39. Mozumder NHMR, Rahman MA, Kamal MS, Mustafa AKM, Rahman MS. effects of pre-drying chemical treatments on quality of cabinet dried tomato powder. Journal of Environmental Science and Natural Resources. 2012;5(1):253-265.
40. Onwuka GI, Nwabara CC, Nwokedi PM, Echendu CA, Asumugha U, Igboekwe MU. Comparative studies of the efficacy of sun drying, solar dryer and hot air oven in the preservation of tomatoes, okra, pepper and onion. Nigeria Food Journal. 2002;20: 10–14.
41. Adetuyi P, Osagie AU, Adekunle AT. Nutrients, anti-nutrients, minerals and zinc bioavailability of okra (*Abelmoschus esculentus* (L) Moench). Journal of American Food and Nutrition. 2011;1(2):49-54.
42. Osunde ZD, Musa-Makama AL. Assessment of changes in nutritional values of locally sun-dried vegetables. AU Journal of Technology. 2007;10(4): 248–253.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/24147