

Original Research Article

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

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 control. Natural open sun drying took about 19¹/₂ hours to dry the okra to 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 10¹/₂ 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 26.04 mg/100g 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/100g 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/100g 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/100g 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 from solar drying method.

Key words: Okra, Drying Method, Chemical properties, Sensory quality

Paper type Research paper

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 (Nosiru *et al.*, 2012). It is a vegetable crop that belongs to the genus *Abelmoschus*, family *Malvaceae* and has two main species: *Abelmoschus esculentus* (L.) Moench and *Abelmoschus caillei* (A. Chev.) Stevels (Sharma, 1993). *Abelmoschus esculentus* (L.) Moench is the widespread specie in tropical, subtropical and warm temperate regions while *Abelmoschus caillei* (A. Chev.) Stevels is

restricted to the humid and perhumid climates of Africa (Siemonsma and Kouamé, 2004). Okra is mainly grown for its tender green pods and leaves, which are cooked and commonly consumed as boiled vegetables (Chattopadhyay *et al.*, 2011). Its total commercial production in the world was estimated at 4.8 million tons, with India and Nigeria being the predominant producers (Gulsen *et al.*, 2007). 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 United State of America, Guino-gombo in Spanish, Guibeiro in Portuguese and Bhindi in India (Ndunguru and Rajabu, 2004). Also in Nigeria, it is known as *Ila* in "Yoruba", *Kubewa* in "Hausa" and *Okwale* in "Igbo" language. Bamire and Oke (2003) reported that there are two distinct seasons for okra farming in Nigeria, the peak and the lean seasons. During the lean season okra are 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 has been widely practiced 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 (Adom *et al.*, 1996; Sobukola, 2009). Okra contains glycans, a substance responsible for the viscosity of aqueous suspension (Owoeye *et al.*, 1990) and the stringy, gum like consistency that is desired in good quality soups (Falade and Omojola, 2010). 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 leucorrhoea backache (Agarwal *et al.*, 2003). 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 (Agarwal *et al.*, 2003).

The essential and nonessential amino acids that okra contains are comparable to that of soybean (Audu *et al.*, 2015). Thus, it plays a vital role in human diet. Audu *et al.* (2015) 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 helps adjust blood sugar by regulating its absorption in the small intestine (Audu *et al.*, 2015). Okra is an excellent laxative treats irritable bowels, heals ulcers and soothes 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 (Audu *et al.*, 2015). 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 (Asian Vegetable Research Development Centre for Africa [AVRDC], 2004; Ngbede *et al.*, 2014).

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 off season at comparatively lesser cost (Hussein *et al.*, 2016a). It is the most efficient, reliable and practically feasible methods of postharvest preservation of okra and other highly-perishable fruits and vegetables (Amer *et al.*, 2010; Hussein *et al.*, 2016a). 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 (Amer *et al.*, 2010; Hussein *et al.*, 2016a). 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 (Hussein *et al.*, 2016a). Hot-air drying is one of the most frequently used operations for food dehydration (Krokida and Maroulis, 1999; Youssef and Mokhtar, 2014). However, drying can accelerate some reactions that can adversely affect the product quality too (Akanbi and Oludemi, 2004; Hussein *et al.*, 2016b). Also it alters other physical, biological and chemical properties of foods (Demirhan and Özbek, 2010; Hussein *et al.*, 2016b). 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 7.00am. 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 (Hussein *et al.*, 2017) 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/100g). The moisture content was determined according to the method of AOAC (2004). 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 (2004) 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 (1g was extracted for ether extract determination using diethyl ether at 64°C as solvent) were determined according to the method of AOAC (2004). The carbohydrate content was determined by difference between 100 and total sum of the percentage of moisture, protein, fat, fibre and ash (AOAC, 1990). 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 (2000) 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 $\pm$ 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 $p < 0.05$ (Hussein *et al.*, 2016a).

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 Figure 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 19¹/₂ 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 10¹/₂ hour 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 (2004), in cabbage, cluster bean, fenugreek, spinach and okra; Wankhade *et al.* (2012) in okra; Kouassi *et al.* (2013) in two varieties of okra dried via sun and electric drying and Hussein *et al.* (2016a) 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%. 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.* (2015) 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 (Hussein and Filli, 2015). 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 (Hussein and Filli, 2015). These factors were observed for high drying rate and lower drying time in the hot air oven drying method.

Ukegbu and Okereke (2013) 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 concentration of nutrients (Morris *et al.*, 2004) and food prepared from dried leafy vegetables has more keeping quality than the fresh one (Achanta and Okos, 2000; Chou and Chua, 2001). Kolawole *et al.* (2010) 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 (Fellows, 1997). Hussein (2016) also reported that to process tomatoes into an intermediate moisture food product, the final moisture content should be lower than 15% in order to maintain

dried products in a stable and low water activity state. The moisture content of the three drying methods used in this study were 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. The result disagree with Elegbede (1998) 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 was found to be more in sun dried samples (Mozumder, *et al.*, 2012).

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 in a short time also prevented melting of the fat thereby increasing their values. Similar results were reported by Audu *et al.* (2015) 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 *et al.* (2002) for dried Okra, Ukegbu and Okereke (2013) for dried Okra and Hussein and Filli (2015) for dried tomato. Ukegbu and Okereke (2013) 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 contain more fiber than the OVD, OSD and FRO. Similar results were reported by Ukegbu and Okereke (2013) for dried okra and Hussein and Filli (2015) for dried tomato. Fiber is useful for maintaining bulk, motility and increasing intestinal tract. It is also necessary for healthy condition, curing of nutritional disorders and food digestion (Ukegbu and Okereke, 2013). The ash and crude fiber of these dried samples corroborate the finding of Adetuyi *et al.* (2011) (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 (2013) 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/100g, which was significantly ($p<0.05$) different from the dried samples. The OSD Okra was 14.08 mg/100g, SLD was 19.21 mg/100g and OVD was 17.14 mg/100g. 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 sun light 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.*, 2016b). Similar results for ascorbic acid contents have been reported by Osunde and Musa-Makama (2007) 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 Figure 2. The degree of difference among the samples were statistically significant at 95% probability level ($p<0.05$). From the

spider chart in figure 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 was ranked highest, having a bright green appearance when compared with the other samples. This was followed by okra dried by open sun and the oven dried samples. The least in appearance was the oven dried okra which had 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.* (2015) for okra and Hussein *et al.* (2016a) 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 indicate 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 is an 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.

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 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.

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382 Table 1: Chemical Properties of Fresh and Dried Okra

Samples	Crude		Crude Fat		Crude fibre		Energy value		Vitamin C
	Moisture (%)	Protein (%)	(%)	Ash (%)	(%)	CHO (%)	(Kcal)	Viscosity (cP)	
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

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384 Values are means of triplicate ±SE, Values in the same column bearing different superscripts are significantly different (p<0.05)

385 Key: FRO = Fresh Okra
 386 OSD = Open Sun Dried
 387 SD = Solar Dried
 388 OVD = Hot Air Oven Dried
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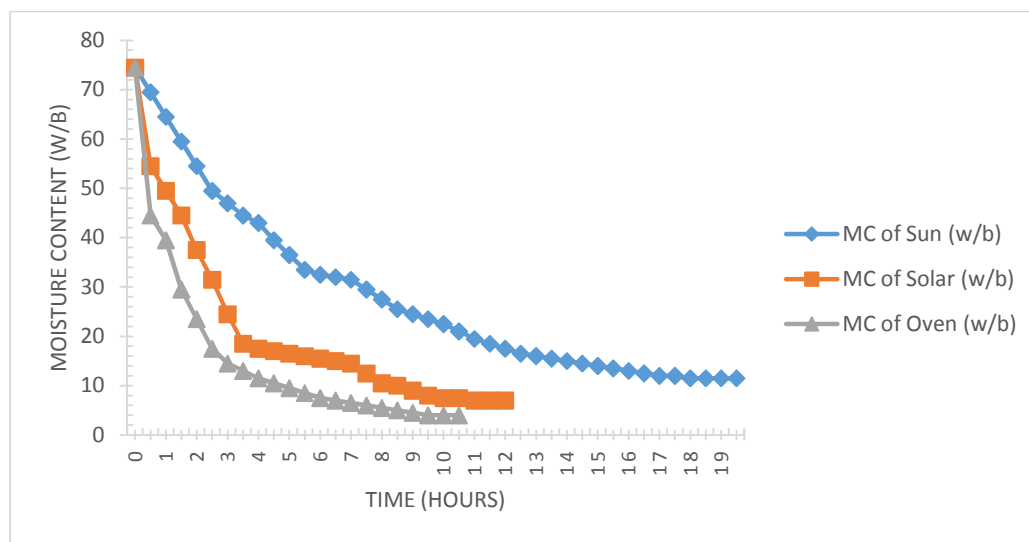


Figure 1: The comparison of okra's drying curves in the oven, solar and open sun drying methods

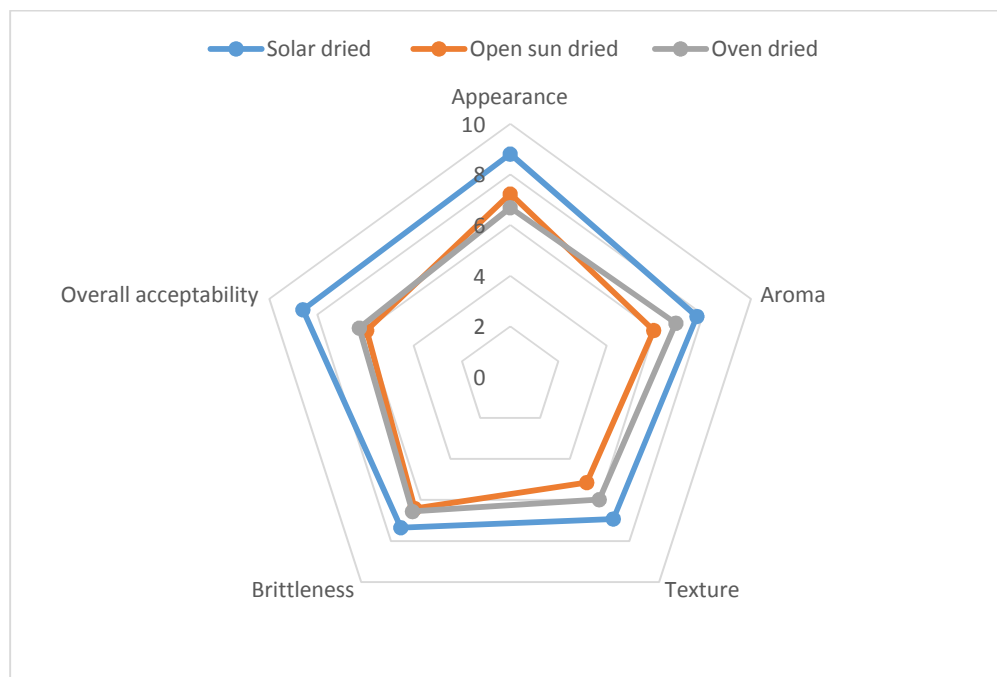


Figure 2: Sensory Evaluation of Dried Okra.