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Effect of Drying Methods on the Nutritional Composition and Microbiological Quality of Selected Vegetables (Okra and Tomatoes).

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ABSTRACT

The study investigated the effects of drying methods on the nutritional composition and microbiological quality of okra and tomatoes. The drying methods employed were; solar and oven drying (50oC and 60oC). Moisture content of the okra and tomato samples decreased when compared with the fresh vegetables (9.56-16.10%)(solar dried),(12.41-17.34% (oven dried 50oC) and 28.19 -39.04% (fresh) respectively. Crude protein for okra and tomato samples ranged from (13.29 - 17.93% (fresh) and 17.70 - 21.71% oven dried 500C). Crude fibre for okra and tomatoes increased (4.34 – 9.42 % (solar dried) and (7.21-12.57 oven dried 500C). Ash content for okra decreased 9.10% (oven dried at 500C)-11.02% (fresh), and 7.16 % (oven dried at 600C) and for tomatoes 7.94% (oven dried 500C),6.65%(oven dried 600C) (9.22% (fresh).Carbohydrate content for okra and tomatoes increased after drying for solar, oven dried at 500C and 600C)(28.08-50.84% and 29.21-48.16%) respectively. Vitamin-C for okra decreased 4.17-15.42mg/100g, and 8.33-36.59mg/100g for tomatoes. Vitamin-A (beta-carotene) for okra and tomatoes decreased from 0.95-13.25mg/100g and19.36-30.71mg/100g respectively. There was an increase in mineral content (K, Fe,Zn, and Ca) after drying for all samples analysed. The microbial load in solar dried samples for okra and tomatoes were high, but low in oven dried for total aerobic plate and fungi count. Some of the suspected microbial flora included: lactobacillus, bacillus spp pseudomonas spp., proteus spp, enterobacter spp, Escherichia coli. The results obtained revealed that solar and oven (500C) drying methods appears to maintain nutritional value (mineral content, proximate composition and vitamins) and acceptable microbial quality for the vegetables assessed.

INTRODUCTION

Vegetables are herbaceous plant that can be eaten as part of a meal to keep man healthy, rich in bioactive compounds and antioxidants that are vital for the human body and prevent the cell from disease-causing free radicals (Rolle, 2020)). Therefore, there is a growing demand for high-quality fruits and vegetables. If vegetables are not properly preserved, they will spoil and their nutritional qualities will depreciate. Drying is a common food preservation technique in the food industry to increase fruits and vegetables shelf-life. According to Lewicki and Lenart (2019), drying is a viable alternative means of preservation of vegetables. Most vegetables are low in calories and have a water content of over 70 percent, with only about 3.5 percent protein and less than 1 percent fat. Vegetables are good sources of minerals, especially calcium and iron, vitamins, principally A and C and are rich in dietary fiber (Lewicki and Lenart, 2019).

Drying is a process through which storage life of food is enhanced. It minimizes the moisture content of food products by weakening the microorganisms that causes deterioration (Nema *et al*., 2015). Oven drying is a thermal process in which heat is supplied by hot air to the products to be dried and the water in the products is removed (Garcia-Gutierrez *et al*,. 2020). Drying of produce of agriculture such as grains, fruits, and vegetables with sun is a very common method because sun is available everywhere. This allows their better storage life, reduction of losses at a time of storage, and reduction in the cost of transportation (Jayaraman and Das-Gupta, 2019). Drying of vegetables can bring about improvement in palatability and digestibility of vegetables, and also brings about change of color, flavor, and appearance of the vegetable (Mierzwa and Kowalski, 2016).

Tomatoes *(Lycopersicon esculentun*) are classified according to their use as fresh consumption and processing. Tomato contains 5.7% dry matter; low concentration of vitamin C, provitamin A and it is rather rich fruit in respect of minerals (especially potassium) compared to other commercially important fruit species (Akanbi and Oludemi, 2004). Tomatoes and tomato-based foods are considered healthy foods for several reasons. They are low in fat and calories, cholesterol-free and a good source of fiber and protein (Shi, 2000). Vitamin C is an important vitamin that is high in antioxidant activity and tomato is the one of the important sources of this vitamin.

Okra *(Abelmoschus esculentus*) is an economically important vegetable crop grown in tropical and sub-tropical corridor of the world (Nicklett *et al*., 2013). This crop is suitable for gardening as well as on large marketable granges. It is a good source of dietary fiber, antioxidants, Vitamins and minerals (Raharjo *et al*., 2019). The traditional system for conserving okra involves slicing and sun drying of the fruits until they come brittle (Abd El-Moniem, *et al*., 2012). It is very perishable because of its high humidity content and respiratory conditioning (Abd El-Moniem, *et al*., 2012). Therefore, preservation of commodity is necessary. In order to prevent the loss of nutritional components of vegetables and to increase their shelf life, there is a need to search for appropriate drying method that is not expensive but highly effective in preserving these locally available vegetables (okra and tomato). The objective of this study therefore, is to evaluate the effect of drying methods on the nutritional and microbiological quality of okra and tomatoes thus, our findings could enable the consumers or food industry to choose either oven drying or solar drying method for maximum retention of nutritional properties and safety in microbiological quality of these vegetables.

2.0 MATERIALS AND METHODS

2.1 Sample collection

The two samples of vegetables used in this study are okra and tomato. They were purchased from new market Wukari, Taraba State and conveyed to the Department of Food Science and Technology in polythene bags for analyses.

2.2 Preparation of Samples

The tomato fruits and okra were sorted from injured and deteriorated fruits, washed under running tap water and weighed. The cleaned fruits were cut into small slices (1cm in length) using sterilized stainless steel knives, and were placed into trays pending the drying process.

2.4 Drying Techniques

For solar drying vegetables were placed inside a solar dryer with perforated trays for better air movement around the samples. The reflection of the sun on the glass increases the drying temperature.

For oven drying, the method of Mbah *et al.*(2012) was engaged with little modification. Each vegetable were placed inside different trays and were dried using force air. The oven was preheated 50^{o}C and 60^{0}C for the two samples of vegetable (tomatoes and okra) and were left for 16 and 12 hours respectively to allow for complete drying. The samples were allowed to cool before they were packed inside air tight container to avoid heat which could lead to caking before analysis.

2.5 Analytical Methods

2.5.1 Determination of the Proximate Composition and Mineral Contents

The proximate composition of the fresh and dried samples of tomato and okra for ash, moisture, crude fat, crude protein (N x 6.25), crude fiber and carbohydrate (by different) were determined in accordance with the methods as described by (Wójcik *et al*., 2021) .All proximate analyses of the samples were carried in duplicate and reported in percentage .All chemical were of Analar grade. The minerals potassium (K), calcium (Ca), zinc (Zn) and iron (Fe)] in the dried vegetables were analysed as described by A.O.A.C (2012) using atomic absorption spectrophotometer(perkin- Elmer Model 403,Norwalk CT).All the minerals determined were reported in mg/100g sample.

2.5.2 Determination of vitamin C and β-Carotene content (Pro-vitamin A)

The quantitative analysis of ascorbic acid content (vitamin C) of fresh, sun dried and oven dried vegetables was carried out using high-performance liquid chromatography-HPLC (Waters Alliance, Milford, Massachusetts, USA) as described by Maia *et al*., (2007). The quantification of ascorbic acid was done using a calibration curve of L-ascorbic acid standard. The β-Carotene content (Pro-vitamin A) of fresh, and oven dried vegetable samples was done using an auto-sampler Shimadzu Ultra-Fast Liquid Chromatography. Sample extraction and mobile phase preparation was done following the methods of (Abd El-Migeed,et al.,(2021) and (Kimura *et al*.,2007). Identification of the all-*trans*-β-carotene was calculated using retinol activity equivalents (RAE) conversion factor of 12 µg β-carotene to 1 µg retinol (Joint FAO/WHO 2003).

2.6 Microbiological Analysis.

2.6.1 Preparation of media

All media used for the enumeration of bacteria cells and isolation of microorganisms from the vegetable samples were prepared according to the manufacturer's instruction.

2.6.2 Isolation and enumeration

Total bacterial count was determined using the method of Obasi *et al.* (2023). The stock solution was prepared by dissolving one millimeter (1ml) of the sample of the fresh and dried vegetable samples in nine millimeter (9ml) of sterile peptone water. Serial dilution (10 fold) was carried out (1:10, 1: 100, 1:1000…10,0000). 1.0ml of appropriate dilutions (10^{-2} and 10^{-4}) was placed on various agar plates using pour plate method and incubated at 37^{0c} for 18-24 hours for total aerobic bacteria and coliform count. For fungi 1.0ml amount of appropriate dilutions (10^{-2} and 10^{-4}) was poured into the plates of potato dextrose agar and incubated at room temperature 28±1^{0c} for 3 to 5 days. All enumeration was expressed as colony forming unit (cfu/ml).

2.6.3 Identification and characterization of the isolates

Bacterial isolates were characterized using routine microbiological procedures as described by Ayeloja *et al.*, (2018) and Obasi *et al.* (2023) after which they were identified using Bergey's Manual of Determinative Bacteriology as described by John *et al* (1994).

3.7 Statistical Analysis

All analysis were carried out in duplicate and data obtained were subjected to one way analysis of variance (ANOVA) using statistical package for social science

(SPSS) version 20:00. Separation of mean values were done using Duncan's New Multiple Range Test (DNMRT) at 5% significance level.

3.0 RESULTS AND DISCUSSION

3.1 Nutritional Composition of the Fresh and Dried Vegetable Samples

3.1.1 Proximate composition of the fresh and dried vegetable samples

Table 4.1 showed the results obtained for proximate composition for moisture, crude protein, fat, crude fiber, ash, and carbohydrate of okra and tomatoes dried with different methods namely; solar dried and oven dried at 50 and 60^{o}C.

The moisture content for the dried okra sample varied between 9.56%-28.59%. There was significant difference ($p<0.05$) between the dried okra samples. The highest moisture content was observed in fresh okra (28.19%) because it does not undergo any drying process. The result also showed variation in the moisture content depending on the drying methods used, with Solar dried okra (9.56%) having the least moisture content. This result was similar to that of Kelechi *et al.,* (2022) who obtained a moisture content of 8.49-29.00%. The moisture content of the dried tomato samples also varied between 16.10%-39.04%. Significant difference ($p<0.05$) exist between the dried tomato samples. The highest moisture content was observed in fresh tomatoes (39.04%) because it does not undergo any drying process (39.04%), the result also showed variation in the moisture content depending on the drying methods used, with Solar dried tomatoes having the least moisture content. This was in line with that of Islam *et al*., (2023) who reported a range of 10.42-30.48% for five leafy vegetable samples. Foods with lower moisture content has the tendency of having a longer shelf life. According to (Adebayo-Oyetoro, 2012), low moisture content of samples would enhance its storability by avoiding mould growth and other biochemical reactions. High moisture content of fruits and vegetables promotes growth of micro-organisms, however drying or dehydration helps to inhibit autolytic enzymes. Drying has been reported to be an effective technique in reducing moisture content thereby, preserving the food and inhibiting microbial contamination (Wachap, 2005). Moisture in food determines the rate of food absorption and assimilation within the body.

Crude protein content of the dried okra samples varied between 19.80%-21.71%. The highest protein content was observed in Oven dried okra 50^{o}C, with oven dried okra 60^{o}C having the least protein content, results obtained from this study were similar to that of Gemede *et al* (2015). The protein content of the dried tomato samples also varied between 16.33%-17.70%. Significant difference ($p<0.05$) exist between the dried tomato samples. The highest protein content was observed in oven dried tomatoes 50^{o}C. The result also showed variation in the protein content depending on the drying methods used, with oven dried tomatoes 60^{o}C having the least moisture, this was similar to that of Ali *et al*., (2023). Ukegbu and Okereke (2013) suggested that drying method and temperature may affect the protein content of vegetables due to higher denaturation of protein cell.

The fat content of the dried okra samples varied between 1.06%- 2.81%. Significant difference ($p<0.05$) exist between the dried okra samples. There was an increase in the fat content after drying. Solar dried okra has the highest fat content when compared to the other dried samples, with the fresh okra having the least fat content. The fat content of the dried tomato samples also varied between 2.10%-9.55%. Significant difference ($p<0.05$) exist between the dried tomato samples as there was an increase after drying. The highest fat content was observed in oven dried tomatoes 50^{o}C. These results for okra and tomato samples were similar to the ones previously reported by Ukegbu and Okereke (2013), 2-4%, and Ali *et al*., (2023) 2-10.04% respectively. The result also showed variation in the fat content depending on the drying methods used, with the fresh tomato having the least fat content. The fat content of fresh samples increased significantly when compared to other samples after drying. This might be due to high moisture content of the sample. Fats are necessary to keep cell membranes functioning properly, to insulate body organs, keep body temperature stable and to maintain healthy skin and hair. (Robert, 2010).

Crude fiber of the four okra samples tend to decrease as there were dried with the fresh sample having the highest amount of fibre. Significant difference ($p<0.05$) exist between the dried okra samples. With oven dried okra 60^{o}C having the highest fibre content, and oven dried okra 50^{0}C with the least fibre content. The fibre content for the dried tomato samples varied from 4.34%-5.46%. Significant difference ($p<0.05$) exist between the dried tomato samples. The highest fibre content was observed in Oven dried tomatoes 50^{o}C. The result also showed variation in the fibre content depending on the drying methods used, with Solar dried tomatoes having the least fibre content, results for okra and tomato samples were similar to that of Ukegbu and Okereke (2013) and Ali *et al*., (2023) respectively, who also reported a decrease in fibre content after drying "ladies finger''. The fibre content was significantly higher in all the dried samples than in the fresh sample. High fibre contents in the dried vegetable were attributed to the loss of moisture and vegetables are good sources of fibre. In addition, it is known that the loss of moisture decreases nutrient density in foods with fibre inclusive (Hussein *et al.,* 2018). Fibre cleanses the digestive tract by removing potential carcinogens from the body and hence prevents the absorption of excess cholesterol. Fibre also adds bulk to food and reduces the intake of excess starchy food, and hence guards against metabolic conditions such as hypertension and diabetes mellitus (Adeyeye, and Osibanjo, (1999), Gemede,*et al*; 2016).

The ash content for the fresh and dried okra samples varied from 7.16%-11.02% with oven dried okra 60°C having the lowest value and oven dried okra 50°C having the highest value. This was slightly different from the 12.24-15.87% obtained by Opega *et al.,* (2017) in dehydrated tomato powder. Total ash content is a reflection of mineral composition of food sample Romdhane, *et al*., (2020). The differences in ash content might be due to variation in biochemical characteristics of the vegetables used (Roby, *et al.,*2019). High values of ash content usually indicate high mineral composition in food samples (Roby, *et al.,* 2019). The ash content for dried tomato samples varied from 6.65%-11.02% with oven dried tomatoes 60°C having the lowest value and oven dried tomatoes 50°C having the highest value. There was a significant difference ($p<0.05$) in ash content between the fresh and each of the dried samples for both okra and tomato samples. The mineral content of a food product is determined by its ash content. High ash content in vegetables indicates high quantity of minerals in the samples (USDA, 2014).

The carbohydrate content for the dried okra sample varied between 28.08%-50.84%. There was significant difference ($p<0.05$) between the dried okra samples. The highest carbohydrate content was observed in solar dried okra. the result also showed variation in the carbohydrate content depending on the drying methods used, with oven dried okra 50°C having the least score for carbohydrate. The carbohydrate content of the dried tomato samples also varied between 29.21%-48.16%. Significant difference ($p<0.05$) exist between the dried tomato samples. The highest carbohydrate content was observed in solar dried tomatoes, with oven dried tomatoes 50°C having the least moisture content. However, values of the fresh sample for okra and tomatoes were significantly different ($P<0.05$) but there was no significant difference between the dried samples. According to Ukegbu and Okereke (2013) various vegetables like African Spinach, fluted pumpkin, tomato and Okra in their fresh state had been noted to be poor source of carbohydrate. However, after drying the carbohydrate content of vegetable increased due to reduction in moisture content (Butt, 2010). Carbohydrates provides energy for the body and that a high proportion of it is required in breakfast meals and weaning formulas (Butt, 2010).

3. 1 Proximate composition of fresh and dried vegetable samples

Sample	Drying methods	Moisture	Crude protein	Crude fat	Crude fibre	Ash	Carbohydrate
Okra	solar	9.56^{g}±0.23	20.21^{b}±0.21	2.81^{c}±0.02	9.42^{b}±0.46	7.18^{e}±0.03	50.84^{b}±0.38
	oven50ºC	12.41^{e}±0.09	21.71^{a}±0.41	2.36^{a}±0.19	7.21^{c}±0.01	9.10^{b}±0.16	47.21^{a}±0.15
	oven60ºC	11.34^{f}±0.14	19.80^{b}± 0.46	2.39^{cd}±0.28	9.56^{b}±0.39	7.16^{e}±0.00	49.77^{bc}±0.71
	Fresh	28.19^{b}±0.04	17.93^{c}±0.10	1.06^{e}±0.07	12.57^{a}±0.62	11.02^{a}±0.00	28.08^{e}±2.02
Tomatoes	solar	16.10^{d}±0.41	16.39^{d}±0.31	7.64^{b}±0.25	4.34^{e}±0.13	7.38^{d}±0.01	48.16^{cd}±0.47
	oven50ºC	17.34^{c}±0.13	17.70^{c}±0.31	9.55^{e}±0.16	5.46^{d}±0.02	7.94^{c}±0.08	42.01^{b}±0.11
	Oven60ºC	16.79^{cd}±0.83	16.33^{d}±0.60	7.99^{cd}±0.28	4.61^{de}±0.47	6.65^{f}±0.01	47.65^{d}±0.98
	Fresh	39.04^{a}±0.00	13.29^{e}±0.05	2.10^{d}±0.03	6.66^{c}±0.49	9.22^{b}±0.15	29.21^{e}±0.29

Values are mean ± standard deviation of the duplicate scores. Means within each column not followed by the same superscript are significantly different ($p \leq 0.05$) from each other using Duncan multiple range test

3.1.2 Vitamin content of the fresh and dried vegetable samples

Table 3.2 showed the results obtained for vitamin A and vitamin C content for fresh and dried samples of okra and tomatoes.

The vitamin C content for the dried okra samples ranges between 4.17-6.84 mg/100g, and 8.33-36.59 mg/100g for okra and tomato sample respectively. Vitamin C content for the fresh samples were significantly higher than that of the dried samples. This result also revealed that the two drying methods differ significantly ($p<0.05$) in the level of Vitamin C. The solar dried samples has higher vitamin retention when compared to the oven dried at 60°C and 50°C. This might be due to low temperature drying in the solar dryer as compared to high temperature of oven drying 60°C and 50°C solar dried samples as vitamins A and C can be lost when heat is applied. Adejumo (2012) similarly reported that Vitamin C can easily be destroyed at high temperature because they are heat sensitive. When fruits and vegetables are exposed to heat, light or high temperature, decrease in Vitamin C could occur (Isack & Lyimo, 2013). Okra and tomato plant contain vitamin C which is beneficial for immune system and also plays an important role in fighting off colds and viruses, vitamin C also helps to decrease the risk of developing further complications like pneumonia and lung infections when taken during cold (Isack *et al.,* 2013). Water loss in foods or dehydration may also induce vitamin losses as reported by Hossain *et al.,* (2015). The results obtained for this study were similar to that of Isack & Lyimo, 2013 who reported almost a similar range of vitamin C in solar dried okra and tomato samples (5.0-7.0 mg/100g for okra and 9.45-37.00 mg/100g for tomatoes).

The vitamin A content ranges between 0.95-13.25 mg/100g, and 19.36-30.71 mg/100g for okra and tomatoes respectively. Vitamin A content for the fresh samples were significantly higher than that of the dried samples. This result also revealed that the two drying methods differ significantly (p<0.05) in the level of Vitamin A. Results for this study was comparable to that of Shonte *et al*., (2020) who obtained a range of 1.2-12.40 mg/100g of vitamin A in oven dried okra samples. Vitamin A is a fat soluble vitamin that is important in normal vision, the immune system, reproduction, and most importantly for growth and development (Isack *et al.,* 2013).

Table 3. 2 Vitamin content of fresh and dried vegetable samples

Samples	Drying methods	Vitamin C	Vitamin A
Okra	solar	$4.17^{g}\pm0.00$	$0.95^{g}\pm0.01$
	oven-50ºC	$6.84^{e}\pm0.01$	$3.00^{f}\pm0.01$
	oven-60ºC	$5.42^{f}\pm0.59$	$2.45^{f}\pm0.01$
	Fresh	$15.42^{b}\pm0.5$	$13.25^{e}\pm0.35$
Tomatoes	solar	$8.33^{d}\pm0.00$	$19.36^{d}\pm0.25$
	oven-50ºC	$10.96^{c}\pm0.06$	$25.07^{b}\pm0.78$
	oven-60ºC	$10.00^{c}\pm1.17$	$23.49^{c}\pm0.04$
	Fresh	$36.59^{a}\pm0.23$	$30.71^{a}\pm0.41$

Values are mean ± standard deviation of the duplicate values. Means within each column not followed by the same superscript are significantly different (p ≤ 0.05) from each other using Duncan multiple range test.

3.1.3 Mineral content of the fresh and dried vegetable samples

Table 3.3 showed the different values of four mineral content for both fresh, dried okra and tomato samples. The potassium content for the fresh and dried okra and tomato samples varied considerably, with values ranging between 299.06-385.73mg/100g and 353.30-524.12 mg/100g for respectively. The fresh samples has the least potassium content, with oven dried-50ºC samples having the highest values of potassium for okra and tomatoes. The potassium content in the fresh samples tend to increase considerably as there were dried. High potassium contents in the dried vegetable were attributed to the loss of moisture and vegetables are good sources of potassium. In addition, it is known that the loss of moisture increases nutrient density in foods with potassium inclusive Adejumo (2012). The potassium content in this study was comparable to the ones obtained by 15851.Etebu, *et al*., (2013) which showed 280.12-360.71 mg/100g for okra and that of Ali *et al*., (2021) showing 350.09-520.57 mg/100g.

The iron (Fe) content for the fresh and dried okra and tomato samples varied considerably, with values ranging between 0.67-4.50mg/100g and 0.46-5.63 mg/100g for okra and tomato samples respectively. The fresh samples has the least iron content, with oven dried-50ºC samples having the highest values of iron for okra and tomatoes respectively. The iron content in the fresh samples tend to increase considerably as there undergo drying. This might be because of the loss of moisture as loss of moisture tend to increase nutrient density in food. Iron is a vital mineral necessary for red blood cell production, oxygen transport to body organs, and the synthesis of certain hormones. The iron content in this study was comparable to the ones obtained by Ali *et al*. (2021). The zinc (Zn) content for the fresh and dried okra and tomato samples varied considerably, with values ranging between 0.60-3.86mg/100g and 0.26-1.28mg/100g for okra and tomato samples respectively. The fresh samples has the least zinc content, with oven dried-50ºC samples having the highest values of iron for okra and tomatoes respectively. The zinc content in the fresh samples tend to increase considerably as they undergo drying. This might be because of the loss of moisture as loss of moisture tend to increase nutrient density in food. Zinc helps in supporting the immune system, it enables the body to make proteins and DNA, contributes to wound healing, and plays a role in childhood growth and development (Deng, *et al*., 2020).

The concentration of Calcium in dried and fresh okra and tomatoes samples ranged from 82.71 to 802 mg/100g and 14.92 to 241.08 mg/100mg. the value for calcium obtained in this study were comparable to that of Opega *et* al,. (2017). As evidenced, Calcium causes physiological development of bone, teeth and muscles and are both associated with vitamin D metabolism (Alghamdi *et* al,. 2018).Children, pregnant and nursing mothers require calcium containing substances for bones and teeth development. Okra can contribute meaningful amount of dietary calcium and potassium which is required for growth, maintenance of bone, teeth and muscle by eating significant quantity Adejumo (2012).

Table 3. 3 Mineral composition of fresh and dried vegetable samples

Samples	Drying methods	Potassium(k)	Iron(fe)	Zinc(zn)	Calcium(ca)
Okra	solar	$385.73^{c}\pm52.34$	$2.99^{de}\pm0.40$	$3.50^{a}\pm0.28$	$780.11^{ab}\pm65.83$
	oven-50°C	$360.36^{c}\pm0.17$	$4.50^{b}\pm0.10$	$3.86^{a}\pm1.22$	$802.50^{a}\pm1.84$
	oven-60°C	$357.62^{c}\pm1.51$	$3.48^{cd}\pm0.06$	$2.08^{b}\pm0.01$	$748.12^{b}\pm12.73$
	Fresh	$299.06^{d}\pm0.08$	$0.67^{f}\pm0.06$	$0.60^{c}\pm0.03$	$82.71^{e}\pm0.41$
Tomatoes	solar	$465.44^{b}\pm0.00$	$5.63^{a}\pm0.11$	$0.54^{c}\pm0.02$	$161.65^{d}\pm3.24$
	oven-50°C	$542.12^{a}\pm0.35$	$3.76^{c}\pm0.48$	$1.28^{a}\pm0.06$	$241.08^{c}\pm0.40$
	oven-60°C	$537.32^{a}\pm0.00$	$2.50^{e}\pm0.18$	$0.66^{c}\pm0.04$	$172.61^{d}\pm9.38$
	Fresh	$353.30^{c}\pm0.24$	$0.46^{f}\pm0.08$	$0.26^{c}\pm0.01$	$14.95^{f}\pm0.07$

Values are mean ± standard deviation of the duplicate values. Means within each column not followed by the same superscript are significantly different ($p \leq 0.05$) from each other using Duncan multiple range test.

3.2 Microbiological Analysis of Fresh and Dried Vegetable Samples

3.2.1 Microbial load of fresh and dried vegetable samples

Figure 3.1 showed the total aerobic plate count for bacteria cells which ranged from $5x10^{3}$ – $7.1x10^{4}$ cfu/ml for the fresh and dried vegetable samples. The fungi count from the fresh, dried okra and tomato samples ranged from $1x10^{3}$-$2.80x10^{4}$ cfu/ml. According to Food and Agricultural Organisation (FAO, 2012), accepted microbial concentration ranges from <10 colony forming units per ml (CFU/ml) to as high as 10^{5} CFU/ml, comparing these standards to the results obtained from this study, all drying methods contains microorganism at a moderate level. The highest count was observed in oven dried-50°C ($4x10^{4}$), and least in the fresh sample ($2x10^{3}$) for the okra samples. Solar dried sample ($7.1x10^{4}$) has the highest and fresh sample ($5x10^{3}$) with the lowest in tomato samples. This contamination may be from the equipment's/machines used for drying, as the equipment cannot be completely sterilized due to their size. The presence of microbial load could also be as a result of contamination from the milling/blending equipment used in the processing. The result of this study is in agreement with the report by other researchers (Samuel, and Orji, 2015). and slightly different from the 7.4×10^{4}-8.0×10^{4} cfu/ml for coliform and 2.4x $l0^{4}$-3.5×10^{4} spores/ml fungi count in tomato juice and tomato paste reported by Deng, *et al*., (2020). Based on the results from this study, the oven dried samples at 60°C were the best for okra and tomatoes based on microbial quality.

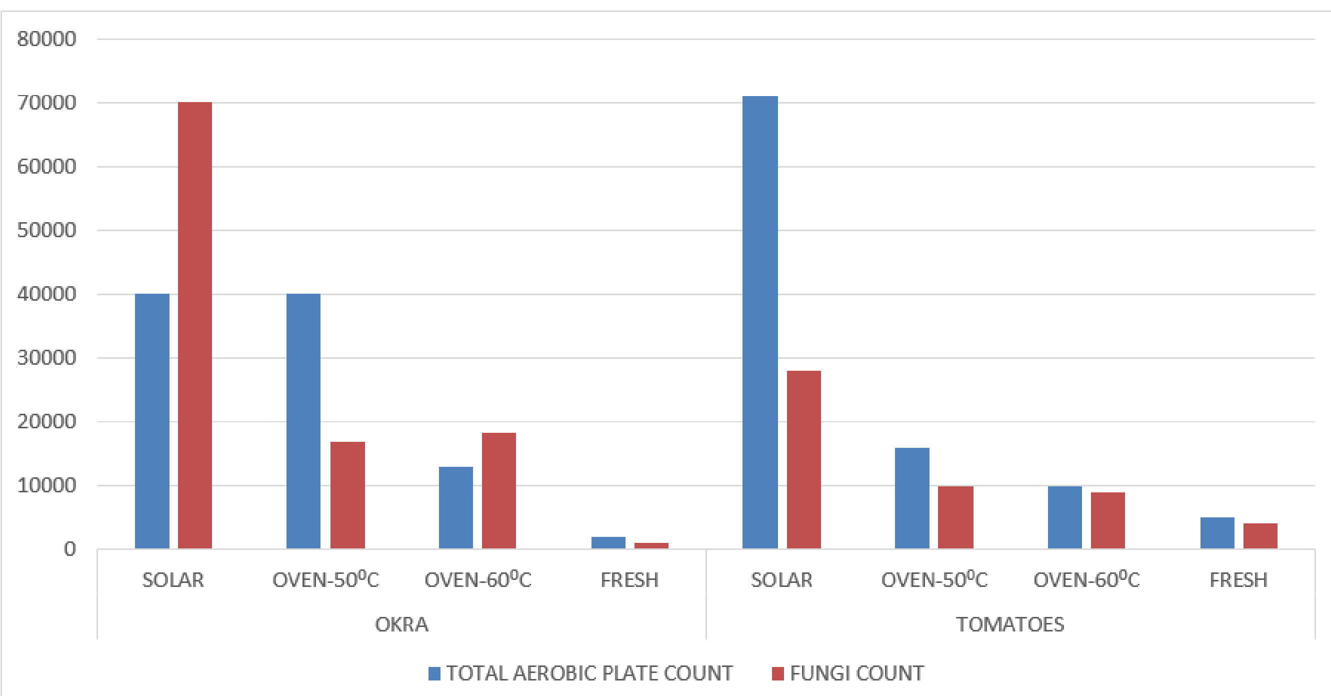

Figure 3. 1 Total aerobic plate count for bacteria cells and fungi count for fresh and dried vegetable samples (okra and tomatoes).

3.2.2 Morphological characteristics of bacterial strains from fresh and dried vegetable samples

The results in Table 3.4 showed the identity of the microorganisms isolated from fresh, dried okra and tomato samples. The suspected microbial species include; *streptococcus, lactococcus, enterococcus species, clostridium, lactobacillus, corynebacterium, listera, streptococci, pseudomonas spp.,salmonella, escherichia coli, proteus spp, citrobacter species, enterobacter spp, Escherichia coli, Staphylococcus , Neisseria, Sarcina , bacilli, pseudomonas spp., bacilli.*

The result of this study is in line with the report of Stanley, *et al*., (2014) who also isolated some diverse microbial species associated with okra and tomato spoilage. The presence of pathogenic Escherichia coli, Streptococcus spp, and Staphylococcus species usually constitute a direct proof of fecal contamination of irrigation water (Obasi and Mani, 2023)). The occurrence of *Staphylococcus species* and *Escherichia coli* in the analysed sample was not surprising as it corroborates with the study of Samuel and Orji, (2015) who reported the isolation of, *Proteus spp*. in dehydrated tomatoes. The identified non-lactic acid bacteria (*E. coli, Bacillus,* and *Proteus species*) reported in this study has also been reported by other authors (Sharma, *et al*., 2020). The thermoduric nature of bacillus spores ensures survival at higher drying temperatures and hence, their presence in the dried vegetable samples under heat.

Table 3.4 Morphological characterization of bacteria from fresh and dried vegetable samples

Sample	Drying Methods	Cell structure	Cell appearance	Pigment	Cell size	Gram Reaction	Suspected organisms
Okra	solar	round	Chain	Yellow	Large	+cocci	*Staphylococcus, Neisseria spp, and Sarcina*
	oven-50ºC	triangular	Single	Yellow	Large	-rod	*pseudomonas spp.,salmonella , proteus spp, citrobacter species*
	oven-60ºC	oval	Cluster	Yellow	Medium	+cocci	*staphylococcus, streptococci*
	Fresh	triangular	Single	Yellow	Small	+rod	*Bacilli, Pseudomonas spp.,Staphylococcus, E. coli*
Tomatoes	solar	rod	Cluster	Milk	Medium	-rod	*Enterobacter spp,*
	oven-50ºC	Rod	Single	Yellow	Large	+ cocci	*Clostridium, lactobacillus, Corynebacterium, Listera*
	oven-60ºC	rod	Chain	Milk	Large	+ cocci	*Streptococcus, Lactococcus and Enterococcus species*
	Fresh	rod	Chain	Milk	Large	+cocci	*E.coli, Pseudomonas spp, Bacilli, Staphylococcus.*

4.0 CONCLUSION AND RECOMMENDATION

This study contributes to understanding the nutritional and microbial profile of these vegetables so as to establish appropriate processing methods that will result in optimum retention of the nutritional parameters as well as ensuring safety of the consumer. Comparing the results obtained from the different drying methods, oven drying method at 50ºC appeared more promising than other drying methods since it maintained mineral content, vitamins and proximate composition of the dried vegetables when compared to the control (fresh sample). Future studies are needed for stability, optimum storage conditions, and suitable packaging materials for dried okra and tomatoes.

Disclosure of conflict of Interest

No conflict of interest to disclosure

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