Effect of Different Drying Methods on Selected Quality Attributes of Okra (*Abelmoschus esculentus* L.)

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ORIGINAL RESEARCH

Abstract— This study examined the impact of different drying techniques and packaging materials on specific quality characteristics of dehydrated okra. The techniques employed for drying and packaging, along with the specific types of dried okra used, should be explicitly described in the Materials and Methods section. The okra samples underwent pre-treatment by immersing them in hot water and salt water prior to being dried using two different ways, namely a laboratory oven and a microwave. The untreated samples were utilised as the control. The desiccated specimens were enclosed in Low Density Polyethylene (LDPE) and High Density Polyethylene (HDPE) pouches and kept in normal environmental conditions for a duration of eight weeks. The quality parameters of pH, colour, and viscosity were tested at two-week intervals for the entire storage duration. The initial pH of the fresh sample was 6.560±0.087. After blanching with fresh water and salt water, the pH climbed to 6.77±0.037 and 6.78±0.041, respectively. The pH further increased when the sample was dried in an oven, reaching 7.03±0.057 and 6.91±0.037. However, the pH declined when the sample was dried in a microwave, resulting in pH values of 6.18±0.051 and 6.39±0.033. The initial colour difference of the fresh sample (45.360±1.197) increased following the process of blanching in fresh water (45.900±1.527) and salt water (47.867±1.221), and subsequently dropped considerably after undergoing oven drying (9.950±1.221, 10.610±1.987) and microwave drying (8.590±1.294, 4.900±0.945). The viscosity of the fresh sample increased from 0.0124±0.003 to 0.0144±0.003 after blanching in boiled fresh water. However, it reduced to 0.008±0.002 after salt water blanching. After oven drying, the viscosity climbed to 0.016±0.001 and 0.0736±0.0257. Similarly, after microwave drying, the viscosity increased to 0.0928±0.0037 and 0.0256±0.007. Both LDPE and HDPE films were deemed suitable for packaging the dried okra samples, as they exhibited minimal contact with the surrounding environment and effectively maintained the quality of the product during the eight-week storage period.

Keywords— Drying methods, okra, packaging materials, quality attributes, storage.

1 INTRODUCTION

Okra, scientifically known as *Abelmoschus esculentus* L. Moench, is a type of vegetable that is grown annually. It may reach a height of 3 to 6 feet and is classified under the *Malvaceae* family (Pendre et al., 2012; Afolabi and Agarry, 2014). Based on FAOSTAT (2020) data, the worldwide output of okra is approximately 9.96 million tonnes, with India being the top producer at 6.18 million tonnes, followed by Nigeria at 1.82 million tonnes. Okra is referred to by many names in different regions of the world. For example, it is called lady's finger in England, gumbo in the United States, guino-gombo in Spain, guibeiro in Portugal, and bhindi in India (Ndunguru & Rajabu, 2004). In Nigeria, this is also known as ila in Yoruba, kubewa in Hausa, and okwale in Igbo.
The cultivation and processing of okra have been extensively practiced due to its nutritional and therapeutic properties (Mohammed et al., 2024). The eating of this perishable vegetable is crucial for nutrition as it contains numerous critical components that promote growth and overall well-being. Okra contains 2% carbohydrates, 3% protein, 12% dietary fibre, 8% calcium, 14% magnesium, 8% potassium, 3% iron, 10% vitamin B6, and 38% vitamin C (Sobukola, 2009). Glycan is present in okra and contributes to the thickness of the liquid mixture (Hussein et al., 2018) and the desired sticky, gel-like texture in soups of superior quality (Falade & Omojola, 2010). Additionally, it serves as a valuable supply of iodine, which is useful for treating goitre. Okra root powder is combined with sugar and used as a treatment for leucorrhoea and backache (Polito et al., 2016).

In Nigeria, okra cultivation is characterised by two different seasons: the peak season and the lean season (Osundare et al., 2024). Okra cultivation is limited during the period of low agricultural productivity, resulting in a scarcity of the vegetable and higher prices. During the peak season, there is a substantial surplus of the product that exceeds the local population's ability to consume it (Bamire & Oke, 2003). To minimise wastage during the peak season, it is crucial to ensure sufficient production, preservation, marketing, and use of okra.

Storing fresh okra fruit poses many challenges for farmers, merchants, and customers (Bisht & Singh, 2024). The high moisture content and respiratory activity of okra cause it to have a limited shelf life, leading to fast deterioration and disintegration after harvest (Falade & Omojola, 2010). After harvest, drying is the optimal technique for preserving okra due to its high efficiency, reliability, and practicality (Amer et al., 2010; Hussein et al., 2016). The study conducted by Hussein et al. (2016) demonstrates that it offers a different approach to utilising okra, minimises losses after harvesting, and makes them more affordable at periods when they are not in season.
Open-air drying is the predominant method of crop drying in developing countries (Goel et al., 2024).

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Although open-air drying has disadvantages, it is nonetheless widely used in regions with sufficient solar radiation (Agbetiloye et al., 2022). It is a sustainable, cost-effective, and eco-friendly option. An inherent drawback of sun drying is its prolonged drying time compared to alternative methods (Tunde-Akintunde, 2011). Additionally, this method exposes the drying materials to potential contamination from dust, insects, and vermin. Therefore, to address these issues, solar or hot air dryers are used to dry okra more efficiently (Doymaz & Pala, 2002; Folayan & Ojo, 2019; Yadav et al., 2024). Additionally, microwave, infrared, oven, and hoover drying techniques are being utilised to address the difficulties associated with open-air drying (Doymaz, 2008; Başlar et al., 2014). Infrared drying has several advantages compared to hot air drying, such as its small equipment design and easily adjustable settings (Sakai & Mao, 2006). One significant benefit of microwave drying compared to conventional drying technologies is its faster drying process, resulting in reduced energy consumption and enhanced quality of the dried food (Ismail & Kocabay, 2016).

When conducting drying operations, it is crucial to meticulously choose the drying variables in order to guarantee the production of high-quality products (Edeh et al., 2024). Enhancing the qualitative qualities of dried okra can be achieved by controlling its drying circumstances, such as minimising its exposure to elevated drying temperatures or shortening the duration of the drying process. Recent endeavours have been undertaken to diminish the duration required for the dehydration of fruits and vegetables, with the aim of enhancing the energy efficiency of the drying procedure and the overall quality of the resultant dried products (Ismail et al., 2019). By subjecting okra pods to a hot air drier, they can be dehydrated and subsequently ground into a fine powder. This process effectively minimises losses that occur after harvesting, while also reducing expenses associated with packaging, storage, and shipping. Various packing materials have been utilised to maintain the quality of dried okra, each with varying levels of effectiveness. This study examined the effects of specific drying techniques and packaging materials on various quality characteristics of dehydrated okra.

2 MATERIALS AND METHODS

2.1 SAMPLE PREPARATION

Okra pods were procured at Bodija Market in Ibadan, Oyo State, Nigeria. Okra samples with lengths ranging from 60 to 100 mm and diameters ranging from 15 to 20 mm were carefully chosen for the investigations. The samples underwent a process of rinsing in purified water to eliminate any dust and extraneous particles, and thereafter were allowed to drain. The depleted samples were subsequently cut by hand using a sharp stainless-steel knife into slices of approximately 2 mm thickness and then separated into two sections. The two halves were subsequently treated using distinct procedures, specifically blanching with hot water and blanching with salty water, each for a duration of 5 minutes. Subsequently, the treated samples underwent several drying techniques. The control group consisted of fresh, untreated okra samples.

2.2 DRYING EXPERIMENTS

Oven drying and microwave drying methods were used in this study. The drying experiments continued until the samples became brittle and readily broken by hand.

2.2.1 OVEN DRYING

A laboratory-type oven (Memmert UF55, 2000 W, Germany) was used for oven drying. The drying temperature was adjusted using a digital control function on the oven. The drying experiment was conducted using treated okra samples in the oven dryer at 50°C temperature level.

2.2.2 MICROWAVE DRYING

Additional samples were subjected to microwave drying using a Qasa Grill QMW-20L microwave oven with a power range of 80-900W in Nigeria. The volume of the microwave drying surface was 262×454×343 mm. It had a revolving glass plate with a diameter of 245 mm at the base of the oven. The microwave oven utilised a digital control system to regulate the power level and duration of the microwave output. The drying experiment was conducted with a microwave power level of 80 W. The okra samples were arranged in a thin layer on the revolving plate inside the microwave oven throughout the drying procedures. The temperature of the drying process inside the microwave oven was determined to be around 50◦C, using a digital thermometer.

2.3 SAMPLE MILLING AND PACKAGING

After the dried samples were let to cool for approximately 10 minutes, they were individually processed into a coarse powder using a blender. The ground okra was placed in two specific packaging materials, High-Density Polyethylene (HDPE) and Low-Density Polyethylene (LDPE) films, which had thicknesses of 0.012 mm and 0.006 mm, respectively. A 100-gram sample of okra powder was placed in each packaging material and stored at room temperature for 8 weeks. The pH level, colour, and viscosity of the dried okra, which are important quality criteria for high-quality soups, were tested at two-week intervals during the storage period.

2.4 DETERMINATION OF QUALITY PARAMETERS

The pH of the okra powder was measured in accordance with the AOAC guidelines (2016). The process entailed dissolving 2.5 g of okra powder by heating it in 100 millilitres of distilled water for a duration of 5 minutes. The resultant solution was chilled briefly and subsequently filtered using a cheesecloth. The pH level of the samples was measured using a digital bench-top pH meter (HI 2211, HANNA pH/ORP Metre). The pH metre was dipped into the sample and the readings were recorded after approximately 3 minutes, once the values had stabilised. The pH meter was calibrated by immersing it in distilled water, resulting in a pH reading of 7.0.

The Chroma meter (Minolta Camera Co. Ltd., model CR-410, Japan) was used to determine the colour of the reconstituted solution sample of okra. Prior to the studies, the Chroma meter was calibrated using a typical white tile with the following colour values: L = 97.63, a = -0.48, b = +2.12.

The viscosity of the reconstituted solution of okra samples was measured using a viscometer (Brookfield Ametek, SCIMED, UK) set to a viscometer tingle number of 63 and a rotating speed of 100 revolutions per minute for a duration of 2 minutes. The viscosity of each sample was tested and recorded. The experiments were conducted in duplicate.

3 RESULTS AND DISCUSSION

3.1 EFFECT OF DRYING, PRE-TREATMENT AND PACKAGING ON THE PH OF OKRA

The pH of the fresh sample increased from 6.560+0.087 to 6.77+0.037 and 6.78+0.041 after blanching in fresh water and salt water, respectively. The pH of the oven-dried samples increased to 7.03+0.057 and 6.91+0.037, while the pH of the microwave-dried samples decreased to 6.18+0.051 and 6.39+0.033 for the fresh water and salt water blanching pre-treatments, respectively. Regardless of the packaging materials utilised, the pH of all the dried okra samples decreased uniformly over the eight-week storage period. Ofori et al. (2020) also documented pH values ranging from 6.41 to 6.48. Figures 1 and 2 display the changes in pH values of the oven-dried and microwave-dried okra samples during an eight-week storage period.

Table 1 displays the results of the analysis of variance for the pH values obtained from the okra samples. The pH of the okra samples was significantly affected ($p \leq 0.05$) by the pre-treatments, which involved blanching in boiled fresh water and blanching in boiled salt water, as well as the drying procedures, which included oven-drying and microwave-drying. The pH of dried okra samples packaged in both LDPE and HDPE packing materials did not show any statistically significant variation ($p \leq 0.05$). The duration of storage had a notable impact ($p \leq 0.05$) on the pH of the dehydrated okra samples in both types of packaging materials. The combined impact of the interactions between drying and pre-treatment procedures had a significant influence ($p \leq 0.05$) on the pH of the okra samples. Nevertheless, the total impact of the interaction between packaging materials, drying processes, and pre-treatments did not have a significant influence ($p \leq 0.05$) on the pH level of okra.

3.2 EFFECT OF DRYING, PRE-TREATMENT AND PACKAGING ON THE COLOUR OF OKRA

Table 2 displays the fluctuations in the colour and thickness of okra samples that were packaged using LDPE and HDPE films during an eight-week storage period. The overall colour difference of the fresh sample increased from 45.360+1.197 to 45.900+1.527 after blanching in fresh water, and further increased to 47.867+1.221 following blanching in salt water. The total colour difference decreased significantly after oven-drying (9.950+1.221, 10.610+1.987) and microwave-drying (8.590+1.294, 4.900+0.945) for the boiled fresh water and salt water pre-treatments, respectively. Furthermore, regardless of the drying procedures and packaging materials employed, there was a consistent overall reduction in the total colour difference observed in the dried okra samples over the storage time. Ismail et al. (2019) documented the variation in colour of dehydrated okra samples using the parameter ΔE, which exhibited a range of 9.62 to 18.93 across various drying techniques. Keshek et al. (2017) also observed similar findings. Figures 3 and 4 depict the changes in colour observed in okra samples that were dried in an oven and in a microwave, respectively, throughout the storage period.

Table 3 presents the outcomes of the analysis of variance for the overall colour of okra samples that were wrapped in LDPE and HDPE films and stored for a duration of eight weeks. The pre-treatments, which involved blanching the okra in boiled fresh water and boiled salt water, as well as the drying procedures, which included using an oven and a microwave, had a noticeable impact ($p \leq 0.05$) on the colour of the okra. The colour of okra samples in LDPE and HDPE films did not show any statistically significant difference ($p \leq 0.05$). Furthermore, the impact of the storage period on the colour of okra samples was not statistically significant ($p \leq 0.05$).

The combined impact of drying processes and packing materials had a significant influence ($p \leq 0.05$) on the colour of okra. However, the combined impact of the interaction between packaging materials and pre-treatment methods, as well as the combined impact of the interaction between packaging materials, drying methods, and pre-treatment, did not have a significant influence ($p \leq 0.05$) on the colour of the okra samples.

3.3 EFFECT OF DRYING, PRE-TREATMENT AND PACKAGING ON THE VISCOSITY OF OKRA

The viscosity of the fresh sample (0.0124+0.003) increased after blanching in boiled fresh water (0.0144+0.003) and decreased after salt water blanching (0.008+0.002). The viscosity of the okra samples rose after being dried in the oven (0.016 + 0.001, 0.0736 + 0.0257) and in the microwave (0.0928+0.0037, 0.0256 +0.007) for the boiling fresh and salt water pre-treatments, respectively. Throughout the storage period, the viscosity of the okra samples reduced significantly in both container materials. Figures 5 and 6 display the differences in viscosity between oven-dried and microwave-dried okra samples.

The findings indicated that the drying techniques had a noteworthy impact ($p \leq 0.05$) on the viscosity of okra, however, the pre-treatments, packaging materials, and storage duration did not exhibit a significant difference ($p \leq 0.05$) in the viscosity of the okra samples. The combined impact of drying and pre-treatment had a significant influence ($p \leq 0.05$) on the viscosity of okra, as well as the combined impact of drying and the materials used for packaging. Nevertheless, the total impact of the interaction between packaging materials and pre-treatments did not have a significant effect ($p \leq 0.05$) on the viscosity of okra. The combined impact of packaging materials, drying processes, and pre-treatment did not have a significant effect ($p \leq 0.05$) on the viscosity of okra.

Table 1:Analysis of Variance of pH on Okr

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Treatment	1	0.2128	0.21282	7.94	0.006
Drying	1	8.5085	8.50850	317.48	0.000
Packaging materials	1	0.0140	0.01402	0.52	0.472
Storage period	3	2.9343	0.97810	36.50	0.000
Treatment*Drying	1	0.4788	0.47884	17.87	0.000
Treatment* Packaging materials	1	0.0794	0.07935	2.96	0.089
Drying* Packaging materials	1	0.0108	0.01084	0.40	0.527
Treatment*Drying* Packaging materials	1	0.0126	0.01260	0.47	0.495
Error	85	2.2780	0.02680		
Lack-of-Fit	21	2.1515	0.10245	51.85	0.000
Pure Error	64	0.1265	0.00198		
Total	95	14.5292			

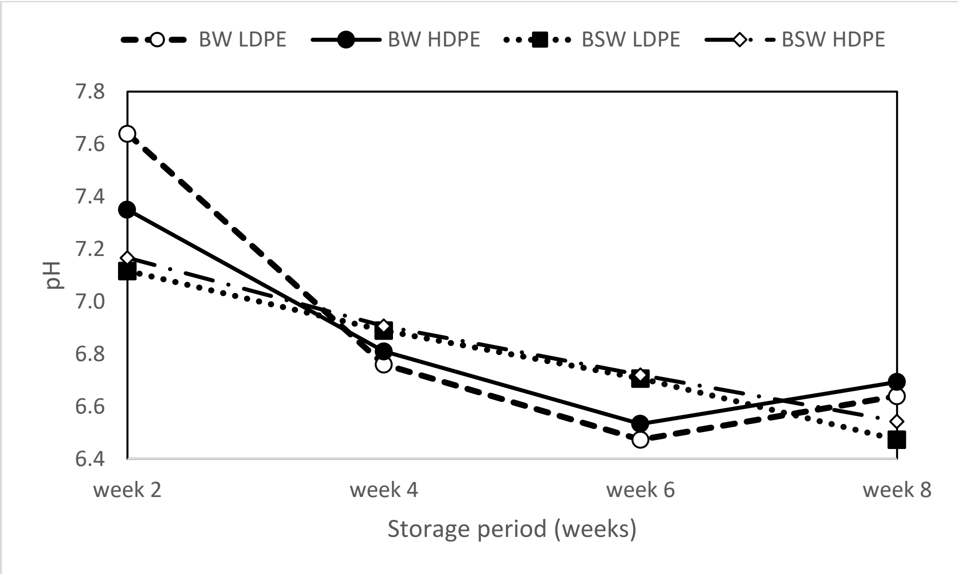

Figure 1: The pH of oven dried okra samples

(Note: BW = Blanched in hot fresh water, BSW = Blanched in salty water)

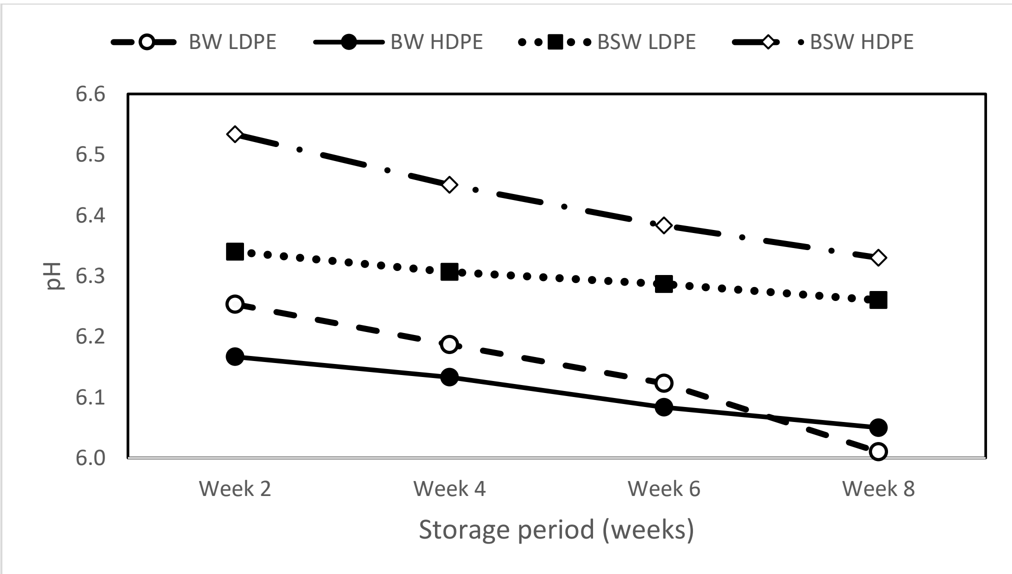

Figure 2: The pH of microwave-dried okra sample

(Note: BW = Blanched in hot fresh water, BSW = Blanched in salty water)

Table 2: Colour of Okra During Storage

Weeks	Treatment	Drying method	Packaging materials	Colour	Viscosity
0	Fresh	-	-	45.36	0.012
0	BW	-	-	45.90	0.014
0	BSW	-	-	47.87	0.008
2	BW	Oven	LDPE	9.84	0.007
2	BW	Oven	HDPE	10.40	0.010
2	BSW	Oven	LDPE	13.88	0.054
2	BSW	Oven	HDPE	15.56	0.018
2	BW	Microwave	LDPE	10.89	0.020
2	BW	Microwave	HDPE	9.78	0.029
2	BSW	Microwave	LDPE	12.72	0.013
2	BSW	Microwave	HDPE	13.36	0.016
4	BW	Oven	LDPE	10.57	0.012
4	BW	Oven	HDPE	12.04	0.010
4	BSW	Oven	LDPE	13.54	0.015
4	BSW	Oven	HDPE	14.41	0.012
4	BW	Microwave	LDPE	10.71	0.023
4	BW	Microwave	HDPE	9.17	0.032
4	BSW	Microwave	LDPE	13.35	0.015
4	BSW	Microwave	HDPE	12.34	0.025
6	BW	Oven	LDPE	11.31	0.012
6	BW	Oven	HDPE	13.52	0.009
6	BSW	Oven	LDPE	13.38	0.012
6	BSW	Oven	HDPE	13.82	0.004
6	BW	Microwave	LDPE	10.51	0.028
6	BW	Microwave	HDPE	8.39	0.036
6	BSW	Microwave	LDPE	12.97	0.016
6	BSW	Microwave	HDPE	11.12	0.039
8	BW	Oven	LDPE	11.87	0.011
8	BW	Oven	HDPE	14.45	0.008
8	BSW	Oven	LDPE	13.08	0.009
8	BSW	Oven	HDPE	13.08	0.005
8	BW	Microwave	LDPE	10.27	0.036
8	BW	Microwave	HDPE	8.00	0.036
8	BSW	Microwave	LDPE	12.36	0.019
8	BSW	Microwave	HDPE	9.27	0.043

Note: BW = Blanched in hot fresh water, BSW = Blanched in salty water

Table 3: Analysis of Variance of Colour on Okra

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Treatment	1	125.150	125.150	76.750	0.000
Drying	1	81.826	81.826	50.180	0.000
Packaging materials	1	0.600	0.600	0.370	0.546
Weeks	3	3.829	1.276	0.780	0.507
Treatment*Drying	1	0.853	0.853	0.520	0.471
Treatment*Packaging materials	1	0.425	0.425	0.260	0.611

Drying*Packaging materials	1	45.968	45.968	28.190	0.000
Treatment*Drying*Packaging materials	1	2.916	2.916	1.790	0.185
Error	85	138.609	1.631		
Lack-of-Fit	21	78.045	3.716	3.930	0.000
Pure Error	64	60.565	0.946		
Total	95	400.176			

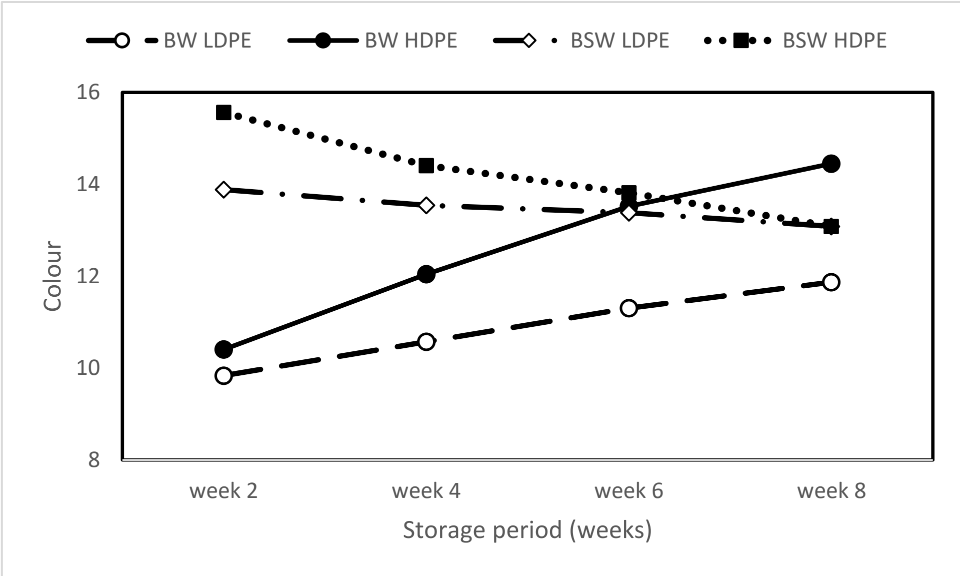

Figure 3: Colour of okra powder for oven drying

(Note: BW = Blanched in hot fresh water, BSW = Blanched in salty water)

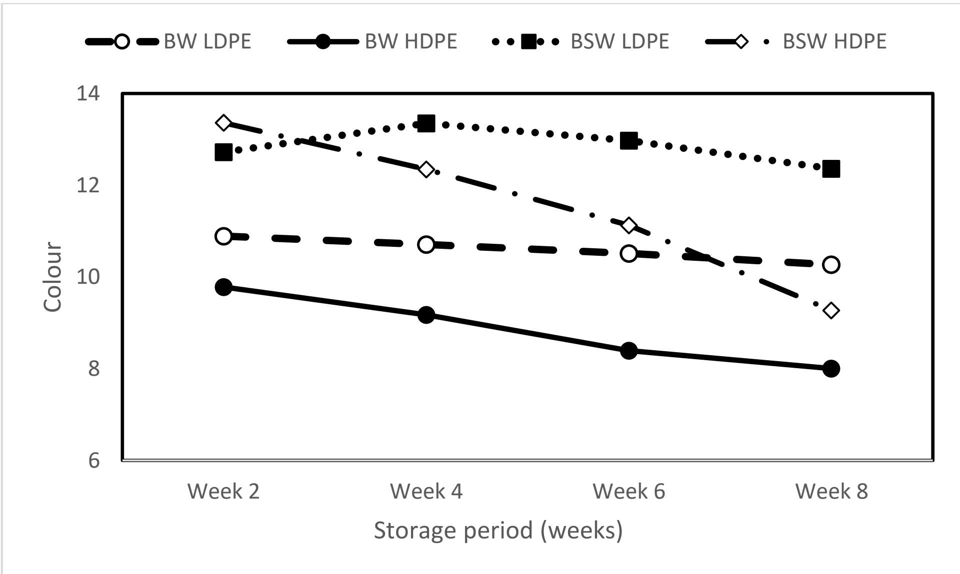

Figure 4:Colour of okra powder for microwave drying

(Note: BW = Blanched in hot fresh water, BSW = Blanched in salty water)

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Table 4: Analysis of Variance on Viscosity of Okra

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Treatment	1	0.000002	0.000002	0.02	0.892
Drying	1	0.004366	0.004366	41.03	0.000
Packaging materials	1	0.000097	0.000097	0.91	0.342
Weeks	3	0.000153	0.000051	0.48	0.696
Treatment*Drying	1	0.000987	0.000987	9.27	0.003
Treatment* Packaging materials	1	0.000015	0.000015	0.14	0.709
Drying* Packaging materials	1	0.001896	0.001896	17.82	0.000
Treatment*Drying*Packaging materials	1	0.000621	0.000621	5.84	0.018
Error	85	0.009044	0.000106		
Lack-of-Fit	21	0.006386	0.000304	7.32	0.000
Pure Error	64	0.002658	0.000042		
Total	95	0.017182			

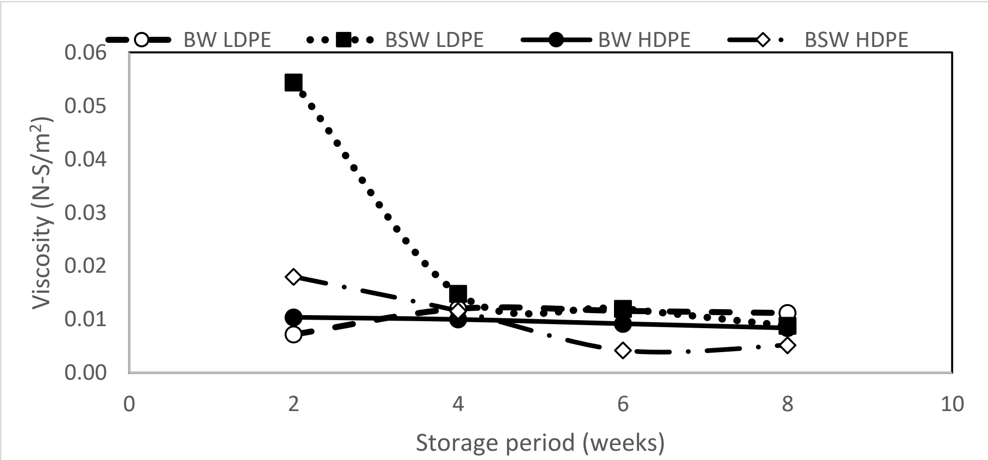

Figure 5: Viscosity of okra powder for oven drying

(Note: BW = Blanched in hot fresh water, BSW = Blanched in salty water)

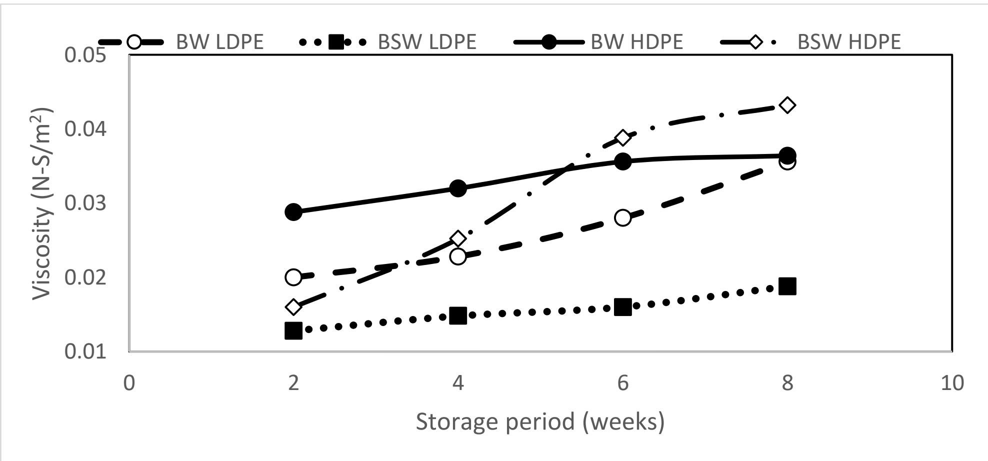

Figure 6: Viscosity of okra powder for microwave drying

(Note: BW = Blanched in hot fresh water, BSW = Blanched in salty water)

4 CONCLUSIONS

This study examined how different drying processes and packaging materials impact specific qualitative characteristics of dried okra. The study found that the pH and colour of okra were significantly influenced by the pre-treatments and drying procedures, but not by the type of packaging materials employed. The drying procedures had a substantial impact on the viscosity of the okra samples, whereas the pre-treatments and packing materials did not have a significant effect on viscosity. Therefore, it is crucial to carefully choose drying processes and pre-treatments in order to maintain the quality of dried okra during storage. Both LDPE and HDPE films were deemed suitable for packaging the dried okra samples due to their capacity to preserve the quality of the preserved samples.

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