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Effects of processing and storage on the nutritional composition of sauces made from two pepper varieties (*Capsicum chinense* and *Capsicum annuum*) and tomato (*Lycopersicum esculentum*)

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Abstract: Processing is important to eliminate harmful microorganisms and extend the shelf life of food. Due to the application of heat during processing and a longer storage period, there is the possibility of nutrient loss. Pepper (*Capsicum* spp) and tomato (*Lycopersicum* esculentum) are antioxidant-rich vegetables known for several pharmacological benefits. The effect of processing and storage on the functionality of sauce produced from pepper and tomato was investigated in this study. The sauce was processed under heat (temperature maintained between 95°C to 98°C for 10 mins) and stored in a glass jar for different periods (1-3 months). Nutritional compositions, *in vitro* antioxidant properties, and phenolic characterization of the samples were evaluated in comparison with a fresh sample. The samples, especially up to 2-month storage, did not significantly differ at p < 0.05 in antioxidant parameters and some nutritional content when compared to the fresh sample. The HPLC characterization of the stored sauces. Capasanthin was the highest compound quantified in the fresh and 1-3 months stored sauce (2.80 mg/g, 3.74 mg/g, 4.83 mg/g, 4.08 mg/g, respectively). Processing did not alter the antioxidant and nutritional compositions, but storing for more than 2 months could cause a decline in some of its nutritional value.

Keywords: Antioxidant, Glass jar, Heat application, Nutrition, Storage.

I. INTRODUCTION

Hot pepper and other spices are regularly used in flavoring, coloring and preserving foods mainly because of their natural colors, aroma, pungency, taste and, more importantly, nutritional compositions [1]. Evidence from research shows the health relevance associated with spicy food consumption [2,3]. Statistically, the consumption of pepper per capita has increased significantly by more than 100% over the last 40 years and thus represents a widely consumed spice coming second after tomato [4]. Pepper is mostly used as a vegetable or spice and it is widely cultivated in Nigeria, accounting for a large percentage of production in Africa [5,6]. This has encouraged the development of spicy products like hot pepper sauce to date. There are several species of pepper (genus *Capsicum*), but the commonly represented ones are *Capsicum chinense* (habanero), *Capsicum annuum* (cayenne, bell pepper), *Capsicum frutescens, Capsicum pubescens,* and *Capsicum baccatum*. Similarly, *Lycopersicum esculentum* (tomato) is one of the major food crops grown and consumed worldwide, with over 80% processed into food products such as juice, sauce (ketchup), soup, salads and paste. They form an important part of nutrition and are known to offer several health benefits which can be attributed to their antioxidant potential [7].

Vol. 12, Issue 2, pp: (40-46), Month: March - April 2025, Available at: www.noveltyjournals.com

Fruits and vegetables are known to be rich sources of antioxidants, thus, the focus on the consumption of pepper and tomato fruits is largely due to their richness in bioactive components that correlate with improving human health and preventing diseases [8]. The exogenous antioxidants are mainly polyphenols, carotenoids and vitamins (vitamins E and C) exhibiting distinct pharmacological effects against inflammation, aging, microbes, and cancer [9].

Thermal processing techniques are used to eliminate harmful pathogens in the food industry and consequently extend their shelf life. In this application, foods are heated with a relatively mild heat below 100°C to reduce the microbial load without significantly affecting the nutritional value [10]. This process is a traditional practice in Nigeria used in the storage of pepper and tomato sauce for convenience and time management. However, the impact of heat and storage on nutritional compositions can vary depending on the specific food and its ingredients. Additionally, the nutritional composition of foods can be altered during processing as some vitamins, minerals, and bioactive compounds may be heat-sensitive and susceptible to degradation. Understanding the effect of thermal processing on food can contribute to optimizing these techniques to preserve their nutritional quality while ensuring their safety and improving shelf life.

This study investigated whether thermal processing and storage alter the nutritional and antioxidant properties of sauce produced from two varieties of pepper, *Capsicum annuum* (Cayenne), *Capsicum chinense* (Habanero), and tomato, *Lycopersicum esculentum*.

II. MATERIALS AND METHODS

SAMPLING

Fresh fruits of *Capsicum chinense* (Habanero), *Capsicum annuum* (Cayenne), and *Lycopersicum esculentum* were sourced from a popular king's market, Ado Ekiti, Ekiti State, Nigeria. They were authenticated and given herbarium numbers UHAE 2023070, UHAE 2023071, and UHAE 2023072, respectively. The pepper (*Capsicum chinense* [25g/100g] and *Capsicum annuum* [25g/100g]) and tomato (*Lycopersicum esculentum* [50g/100g]) fruits were washed clean and blended into a sauce.

SAMPLE PREPARATION

Heat application and storage

The blended pepper and tomato sauce was boiled for 10 mins, after which it was immediately transferred to a glass jar (450 ml). The lid of the glass jar was properly tightened to prevent contamination and the introduction of water while re-boiling. The airtight glass jar was transferred to boiling water for 30 minutes and thereafter stored on the shelf for as long as the experiment lasted. The sauce was stored for different periods (1 month, 2 months, and 3 months). A fresh sample of the sauce was also prepared as a standard for comparison.

Determination of Proximate Composition

The proximate content of sauce produced from two species of *Capsicum* and *Lycopersicum esculentum* was evaluated using the protocol described by the Association of Official Analytical Chemists [11].

Determination of in vitro antioxidant properties

The antioxidant properties of fresh and processed sauce produced from two species of *Capsicum* and *Lycopersicum esculentum* were evaluated using referenced protocols. Total phenol expressed as gallic acid equivalents, mg/g GAE [12], total flavonoid expressed as quercetin equivalent, mg/g QE [13], DPPH radical scavenging ability [14], ferric reducing power expressed as ascorbic acid equivalent, µmol. AAE/g [15], hydroxyl radical scavenging ability [16]. The inhibition of lipid peroxidation was measured by the level of TBARS produced [17].

Characterization of phenolic constituents using HPLC analysis

The method reported by Oboh et al. [16] was used to identify the phenolic contents present in fresh and processed sauce produced from two varieties of *Capsicum* spp and *Lycopersicum esculentum*. The polyphenol components of the samples were identified using retention time and UV spectra in comparison with reference standards. The samples and standard were dissolved in acetonitrile solution (70:30), respectively. The analytical column used was C18 (4.6 mm x 150 mm) packed with 5 μ m diameter particles under gradient conditions.

Novelty Journals

Vol. 12, Issue 2, pp: (40-46), Month: March - April 2025, Available at: www.noveltyjournals.com

DATA ANALYSIS

Replicate readings recorded during analysis were expressed as mean \pm standard deviation using GraphPad Prism 6.0. Oneway ANOVA and Tukey's test were statistically employed (p < 0.05) for multiple comparisons. The IC₅₀ values of the antioxidant assay were evaluated with non-linear regression.

III. RESULT AND DISCUSSION

Proximate composition of fresh and processed sauce

The proximate composition (g/100g) of fresh and processed sauce is presented in Table 1. The moisture content ranged between 4.92 in sample C to 12.1 in sample B; ash content 1.09 in B to 4.19 in D; crude fat 2.43 in D to 6.73 in A; crude protein 6.98 in A to 16.0 in D; crude fibre 2.78 in B to 13.7 in C; carbohydrate content 57.7 in C to 70.8 in A. Thermal processing improves the shelf life of food samples by removing water through heating, thus, the moisture content is an accurate qualitative evaluation taken in food processing. The low content of moisture observed in the processed sauce prevented spoilage for up to 3 months of storage [18]. Despite having significantly (p < 0.05) different appearance and overall acceptability, the low moisture content of the 3-month sauce justifies a non-significant change in its aroma. Fibre is an important food component essential in reducing the risk of chronic and age-related disorders. Thermal processing and storage increased (p < 0.05) the fibre content of the sauce as observed in the processed sauce stored for 2- and 3-month periods, with values higher than those found in indigenous soups reported in OlugbuyI et al. [19]. This makes them beneficial in health and disease management. The ash content of A-D (1.41, 1.09, 3.94, 4.19) and crude protein of A-D (6.98, 9.69, 15.7, 16.0) increased with increasing storage periods. The increasing crude protein implies that the temperature used did not alter the configuration of the protein in the sauce, and as such can be beneficial for replacing worn-out tissues and immune function [20].

Parameters		Sample			
	А	В	С	D	
Moisture	$9.07\pm0.04^{\text{b}}$	12.1 ± 0.07^{a}	4.92 ± 0.24^{c}	5.10 ± 0.00°	
Ash	$1.41\pm0.02^{\rm b}$	1.09 ± 0.01^{b}	3.94 ± 0.14^{a}	$4.19\pm0.02^{\mathtt{a}}$	
Crude fat	6.73 ± 0.23^{a}	4.28 ± 0.02^{b}	4.12 ± 0.13^{b}	$2.43\pm0.02^{\text{c}}$	
Crude protein	$6.98 \pm 0.03^{\circ}$	9.69 ± 0.01^{b}	15.7 ± 0.04^{a}	16.0 ± 0.04^{a}	
Crude fibre	5.00 ± 0.00^{b}	2.78 ± 0.19^{c}	13.7 ± 0.27^{a}	13.5 ± 0.05^{a}	
Carbohydrate	70.8 ± 0.26^{a}	70.0 ± 0.25^{a}	57.7±0.25b	59.6 ± 1.42 ^b	

Table 1: Proximate composition of sauce produced from two varieties of pepper (Capsicum chinense and Capsicum
annuum) and tomato (Lycopersicum esculentum) (g/100g)

Values represent means \pm standard deviation of replicate readings

Values with different superscripts across rows are significantly different, p < 0.05

A: Fresh; B: 1 month storage; C: 2 months storage; D: 3 months storage

Antioxidant properties of fresh and processed sauce

The total content of phenol, flavonoid, and the reducing power of the sauce produced from two varieties of *Capsicum* spp. and *Lycopersicum esculentum* is presented in Table 2. The total phenol (mg/g GAE) and flavonoid (mg/g QE) content of the fresh, 1- and 2-month stored samples were not different (p > 0.05) from each other except for 3 months stored sample having a reduced total content of phenol (12.6 mg/g) and flavonoid (3.99 mg/g). Similarly, the ferric reducing power of the fresh and 2-month processed and stored samples was significantly higher than the 1- and 3-month stored samples. Functional

Vol. 12, Issue 2, pp: (40-46), Month: March - April 2025, Available at: www.noveltyjournals.com

food plays a crucial role in maintaining the health of the human body. They exhibit antioxidant, antimicrobial, antihyperglycemic, anti-inflammatory, and immune system promotion properties due to the phenolic compounds they carry, and as such important for nutraceutical applications [21].

 Table 2: Total phenol, total flavonoid content, and ferric reducing antioxidant power of sauce produced from two varieties of pepper (*Capsicum chinense* and *Capsicum annuum*) and tomato (*Lycopersicum esculentum*)

	Α	В	с	D
Total phenol (mg/g GAE)	13.9 ± 0.11^{a}	$13.3\pm0.03^{\mathtt{a}}$	$13.0\pm0.01^{\mathtt{a}}$	12.6 ± 0.06^{b}
Total flavonoid (mg/g QE)	5.14 ± 0.04^{a}	4.61 ± 0.01^{b}	5.34 ± 0.02^{a}	$3.99\pm0.00^{\rm c}$
FRAP	8.45 ± 0.30^{a}	6.47 ± 0.02^{b}	$7.53 \pm 0.37^{\mathtt{a}}$	6.26 ± 0.06^{b}

Values represent means ± standard deviation of replicate readings

Values with different superscripts across rows are significantly different, p < 0.05

A: Fresh; B: 1 month storage; C: 2 months storage; D: 3 months storage

The free radicals (DPPH and OH) scavenging ability is presented in Fig. 1, and these did not differ significantly (p < 0.05) from each other based on their IC₅₀ values presented in Table 3.

The 2-month stored sample ($IC_{50} 0.32 \text{ mg/ml}$) scavenged OH radicals better than the fresh sauce ($IC_{50} 0.41 \text{ mg/ml}$). The anti-oxidative properties of functional foods are mediated through scavenging and suppressing the formation of reactive species (ROS/RNS), and chelation of metals linked to the generation of free radicals [22]. The antioxidant potential of pepper species was confirmed in the study of Ayob et al. [23], who determined the DPPH, hydroxyl radical scavenging activity, and ferric-reducing power of three varieties of Himalayan red chili. The processed sauce in this study scavenged DPPH and OH radicals and reduced ferric ions.



Figure 1: DPPH and OH radical scavenging ability of sauce produced from two varieties of pepper (*Capsicum chinense* and *Capsicum annuum*) and tomato (*Lycopersicum esculentum*)

The Fe^{2+} induced lipid peroxidation inhibitory effect of the sauce is presented in Fig. 2, and its IC₅₀ value is presented in Table 3.





Figure 2: Inhibition of Fe²⁺ induced lipid peroxidation by sauce produced from two varieties of pepper (*Capsicum chinense*, *Capsicum annuum*) and tomato (*Lycopersicum esculentum*)

Both fresh and processed samples prevented lipid peroxidation with no significant difference (p > 0.05) between them. Oboh et al [24] reported similar prevention of lipid peroxidation induced by Fe²⁺ in the brain by two varieties of pepper.

Table 3: IC₅₀ (µg/ml) values of DPPH, OH radical scavenging abilities, and Fe²⁺ induced lipid peroxidation inhibitory effect of sauce produced from two varieties of pepper (*Capsicum chinense* and *Capsicum annuum*) and tomato (*Lycopersicum esculentum*)

	А	В	С	D
DPPH*	0.29 ± 0.00^{a}	0.34 ± 0.00^{a}	0.30 ± 0.01^{a}	0.43 ± 0.01 ^b
OH*	0.41 ± 0.00^{a}	$0.49\pm0.01^{\mathtt{a}}$	0.32 ± 0.00^{b}	0.34 ± 0.00^{b}
LPO	0.21 ± 0.00^{a}	0.19 ± 0.00^{a}	0.18 ± 0.00^{a}	0.20 ± 0.00^{a}

Values represent mean \pm standard deviation of replicate readings

Values with the same superscripts across rows are not significantly different, p > 0.05

A: Fresh; B: 1 month storage; C: 2 months storage; D: 3 months storage

HPLC characterization of fresh and processed sauce

The phenolic quantification (mg/g) of fresh and processed sauce from two varieties of pepper (*Capsicum chinense* and *Capsicum annuum*) and tomato (*Lycopersicum esculentum*) is presented in Table 4. The results revealed capsanthin as the highest compound identified in the fresh and processed sauce stored for 1-3 months (Capsanthin: 2.80 mg/g, 3.74 mg/g, 4.83 mg/g, 4.08 mg/g, respectively). Capsanthin is important in human health as an antioxidant, anti-inflammatory agent, and skin protectant [25, 26]. Additionally, β -carotene was identified in the 2-month (0.37 mg/g) and 3-month (0.37 mg/g) stored sauce, while Xanthophyll (0.46 mg/g) and capsorubin (0.40 mg/g) were solely identified in the 3-month stored sauce. The concentration (mg/g) of phenolic compounds identified in the processed sauce increased with the length of the storage period. This suggests that thermal processing did not alter the nutritional value. The presence of extra phenolics in the 2-month processed and stored sauce might be because of storage, and a decline in the 3-month sauce suggests that a longer storage period reduces the bioactive constituents of the sauce.

Vol. 12, Issue 2, pp: (40-46), Month: March - April 2025, Available at: www.noveltyjournals.com

Compounds	Concentration (mg/g)			
A	В	С	D	
Beta-Carotene	-	-	0.37	0.37
Capsaicin	1.85	2.10	2.70	2.39
Dihydrocapsaicin	1.32	1.32	1.35	1.35
Phytofluene	0.61	0.75	0.88	0.83
Trans-b-ocimene	0.48	0.56	0.71	0.69
Methylsalicylate	0.37	0.45	0.83	0.61
Lutein	0.46	0.77	0.92	0.92
Capasanthin	2.80	3.74	4.83	4.08
Delphinidin	0.25	0.32	0.65	0.42
Limonene	0.23	0.44	0.47	0.46
Cryptoxanthin	0.27	0.31	0.36	0.42
Xantophyll	-	-	0.46	-
Capsicoside	0.28	0.33	0.53	0.62
Capsorubin	-	-	0.40	-

 Table 4: Phenolic identification and quantification of sauce produced from two varieties of pepper (Capsicum chinense and Capsicum annuum) and tomato (Lycopersicum esculentum)

A: Fresh; B: 1 month storage; C: 2 months storage; D: 3 months storage

IV. CONCLUSION

The thermal processing of sauce produced from two varieties of pepper (*Capsicum annum*, *Capsicum Chinense*) and tomato (*Lycopersicum esculentum*) did not alter the nutritional, antioxidant, and phenolic compositions of the sauce. Storage for up to 2 months improved the phenolic composition of the sauce. However, ways to improve the longer storage periods of the processed sauce can be devised to extend its shelf life without nutrient loss.

Declaration of competing interest

The authors declare no competing financial interests or personal relationships that are relevant to the content of this article.

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Vol. 12, Issue 2, pp: (40-46), Month: March - April 2025, Available at: www.noveltyjournals.com

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