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Original Article

Impact of magnetic field strength and pretreatment times on quality of pulsed electromagnetic field - treated shallot (*Allium ascalonicum* L.) Powder

OPEN ACCESS

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ABSTRACT

Shallot is a spice vegetable that belongs to the allium group like onion, with a stronger aroma and appetising taste, but could leach during blanching. The effects of different magnetic field strengths (MFS) and pretreatment times (PT) on the quality of Pulsed Electromagnetic Field Treated Shallot Powder (PEMFT-SP) and the sensory properties of Smoked Meat (Soya) spiced with PEMFT-SP were evaluated. Shallot bulbs were treated at different MFS (8.00 to 24.00mT) and PT (5 to 25 minutes) using PEMF device. The treated samples were oven dried (at 60°C for 5 hrs) and then milled into powder. A control sample was produced by using blanching as pretreatment. Samples were analysed for chemical and sensory properties using standard methods. Chemical and organoleptic quality of PEMFT – SP were significantly varied with MFS and PT. Vitamin contents of PEMFT-SP had the highest retention at 24.00mT for 10 minutes. Mineral content of the SP samples was significantly higher than the control. Antioxidant capacity of the PEMFT-SP had the highest retention at 13.50mT for 20mins. Except for phytate, blanching as a pre-treatment was more effective than PEMF (8.00 to 30.00mT for 5 to 25mins) in the reduction of antinutritional properties. Sensory panellists judged the PEMFT-SP at MFS 24.00mT for 10 minutes to be of best acceptability. Therefore, pretreatment of SP with PEMF retained the vitamins, minerals and antioxidant content. However, studies on optimization of MFS and PT for PEMF-treatment of shallot or similar species are recommended.

KEYWORDS: *Antioxidants, Food seasoning, Shallot, Spices, Vitamins contents*

INTRODUCTION

Spices are aromatic plant parts, such as tree bark, flowers, buds, fruits, rhizomes, seeds, leaves, roots, stigmas and styles, commonly used for flavouring and preservation of food or beverages (Arachchige *et al.*, 2021). The commonly used spices include ginger, pepper, onion, garlic, shallots amongst others (Herman, 2015). Shallot is a spice vegetables and part of the allium group like onion with a more intense aroma and taste (Sun *et al.*, 2019). It comes in clusters of small cloves and bulbs and serves as important seasonings for enhancing the taste of dishes and for medicinal purposes. It is very rich in vitamins A, B, C, fibres, minerals, protein and phytochemicals such as polyphenols and flavonoids (Sun *et al.*, 2019; Sittisart *et al.*, 2017). Study has shown that it has a lot of therapeutic properties such as antibiotic, hypolipidemic, anticancer, antioxidant, hypoglycaemic, kidney protective and

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hepatoprotective properties (Sun *et al.,* 2019). In a bid to enhance its shelf life and usage, shallot is usually being processed into powder (Kubec *et al,* 2018), during which its vegetables may develop a bitter taste when exposed to very high heat due to the formation of Allithiolanes. Furthermore, during processing of shallot into powder, the enzymatic browning reaction of phenolic compounds, catalysed by polyphenol oxidase do occur, leading to the formation of undesirable colour and flavour and the loss of nutrients (Zhu *et al.,* 2022). Thus, a need to pretreat shallots before drying is necessary. Pre-treatment is a method used before drying of agro products to incapacitate enzymes, improve drying process and enhance quality of dried products.

Food pre-treatment methods can be classified into conventional and non-conventional (novel technology) methods (Neeto & Chen, 2014). Conventional food pretreatment includes both the thermal and non-thermal techniques. Thermal techniques have been widely employed in food industries for food processing. However, thermal processing may cause some undesirable changes or form byproducts that can adversely affect the nutritional value, flavour, colour and texture of final products (Chauhan & Unni, 2015). Hence, the need to investigate non-thermal processing technologies is imperative. Typical examples of non-thermal pretreatment methods includes High Hydrostatic Pressure (HHP), irradiation, pulsed light, Ultrasonics, Pulsed X-Rays and the use of the magnetic field such as Pulsed Electromagnetic Field (PEMF) (Neeto & Chen, 2014). Pulsed Electromagnetic Field (PEMF) technology encompasses the generation and powerful direction of pulsed electromagnetic waves to liquid or semi-solid foods placed between two electrodes. The generated waves in turn react with the cells that come in contact with it thereby changing the state of the electron's spin system (Pawluk, 2015). It works on the principle of electromagnetism wherein magnetic field is generated only when current is flowing through electrical wire coiled around a core. The effects of PEMF technology on food products has not been thoroughly studied; however, it is considered to be a promising non thermal technology for the inactivation of microorganisms (Seyfali *et al.,* 2024). PEMF technology has an extensive array of applications ranging from liquid or semi-solid foods to solid foods (Takaki *et al.,* 2021).

The few studies of PEMF have focused on its treatment effects on the microbial inactivation in milk, milk products, juice, egg products and other liquid foods while a limited amount of information is available about the effect of this technology on food constituents and overall quality and acceptability. Hence, this study is aimed at evaluating the impact of magnetic field strength and pretreatment time on the quality of shallot powder.

MATERIALS AND METHODS

Materials

A locally manufactured electromagnetic field pre-treatment device at the Department of Food Engineering, Federal University of Technology, Akure, Ondo State was used for the Pre-treatment. Electronic weighing balance, cabinet oven and desiccator were also obtained from Federal University of Technology, Akure, Ondo State. Fresh samples of shallots were obtained from Mile 12 market, Lagos State. Smoked meat (suya) was obtained from a smoked meat vendor in Ilorin, Kwara State.

Methods

Pre-treatment of shallot and production of shallot powder

Fresh samples of shallot bulbs were sorted, washed and cut into smaller pieces. After this, uniform experimental quantities per run (100g) was measured with the electronic weighing balance. The measured samples were then placed in the pulsed-electromagnetic field device. Selection of magnetic field strength (8 - 30 mT) and Pre-treatment time (5 - 25 min) was done on the electromagnetic field device (Table 1) (Odewole *et al.,* 2022). The control was blanched by scalding the sliced shallot sample in boiling water at 80 to 100 ˚C for 5 to 10 minutes. All pulsed-electromagnetic field pre-treated and blanched samples were dried in the cabinet drier at 60˚C and briefly kept in the desiccator to prevent the dried products from absorbing moisture.

Table 1: PEMF Strengths and PT for the Production of Shallot Powder.

Samples	Voltage (V)	MFS (mT)	PT (minutes)
NAS	3.2	8	25
ESO	5	13.5	20
FUL	6.6	19	15
KAZ	8.3	24	10
TON	10.1	30	5
ELA (control)	Nil	Nil	Nil

MFS – Magnetic Field Strength (mili Telsa): PT – Pretreatment Time (minutes)

Chemical analyses

Determination of vitamin composition

The contents of Vitamin C, A, B9 and B6 in the shallot samples were determined using the method described by the outlined procedure of the Association of Official Analytical Chemists (AOAC, 2005).

Determination of mineral composition

Four macro minerals (Na, Ca, K, P) and two micro minerals (Fe, Zn) concentration of the test samples were determined by the dry ash extraction method following each specific mineral element as described by AOAC (2005).

Phytochemical composition

Determination of antioxidant properties

Total antioxidant activity was determined based on the reduction of Mo (VI)-Mo (V) by the extract and the subsequent formation of a green phosphate/Mo (V) complex at acidic pH as described by Prieto, *et al*, (1999). The antioxidant activity was expressed as gallic acid equivalent. The total phenol content of the extract was determined by the method of Singleton *et al.*, (1999). The total flavonoid content of the extract was determined using a colourimeter assay developed by (Bao, 2005). Absorbance was read at 510nm against the reagent blank and flavonoid content was expressed as mg rutin equivalent.

Determination of anti-nutrient properties

The Phytate content was determined using the AOAC (2005) method. The AOAC (2019) method was used to determine the tannin content. While Oxalate content was determined according to the procedure adopted by Onwuka (2005).

Sensory evaluation of smoked meat spiced with PEMFT-SP at different MFS and PT.

The six (6) samples were applied on smoked meat (suya) and presented to 30 panellists for evaluation based on a 9-point hedonic scale. Sun dried onion powder served as the control. The samples were evaluated based on aroma, colour, appearance, taste and overall acceptability.

Statistical analysis

All generated data in triplicate, were subjected to Statistical Package for Social (SPSS Version 21) software. The means were separated, using Duncan's multiple range test ($p<0.05$).

RESULTS AND DISCUSSIONS

Vitamin Composition of PEMFT-SP as influenced by MFS and PT

Vitamin composition of PEMFT-SP in KAZ (24MFS:10PT) was predominantly higher than those of other samples and control, except in vitamin B9 (Table 2.). Vitamin (C, B9, B6 and A) contents ranged between (39.15- 44.20 Mg/g; 0.05 - 0.06 (Mg/g; 0.01-0.03mg/g and 1333.26-1632.99mg/g) respectively. The implication of this is that the application of PEMFPT retains these Vitamins of importance better than Blanching. The result agreed with the findings of other authors (Odriozola-Serrano *et al*, 2013). The values recorded in this study were considerably higher than the values (0.2-3.8 g/100g) recorded by Armand et al, (2018) on some wild plants used as spices in Cameroon and the values (1.32 - 4.97 Mg/100g) recorded by Dodo *et al*, (2020) on five Nigerian spices. It was also similar to the values (2.21-7.49 Mg/100g) recorded by Kebede *et al*, (2019) on improved onion bulbs varieties.

Table 2: Vitamin Composition of PEMFT-SP influenced by MFS and PT

SAMPLES	MFS (mT)	PT (mins)	VIT C (Mg/g)	VIT B9 (Mg/g)	VIT B6 (Mg/g)	VIT A (Mg/g)
NAS	8.00	25	40.27 ± 0.07^d	0.06 ± 0.00^a	0.02 ± 0.00^b	1557.79 ± 2.06^d
ESO	13.50	20	39.15 ± 0.07^f	0.06 ± 0.00^a	0.01 ± 0.00^c	1333.26 ± 2.25^e
FUL	19.00	15	42.47 ± 0.07^c	0.06 ± 0.00^a	0.02 ± 0.00^b	1564.35 ± 1.50^c
KAZ	24.00	10	44.20 ± 0.06^a	0.05 ± 0.00^b	0.03 ± 0.00^a	1632.99 ± 1.48^a
TON	30.00	5	40.07 ± 0.06^e	0.05 ± 0.00^b	0.02 ± 0.00^b	1431.70 ± 1.88^e
ELA	NIL	NIL	43.05 ± 0.06^b	0.05 ± 0.00^b	0.02 ± 0.00^b	1576.49 ± 1.64^b

Means with the same superscript in the same column are not significantly different ($P \leq 0.05$)
MFS: Magnetic Field Strength: PT: Pretreatment Time

Mineral Composition of PEMFT-SP influenced by MFS and PT

There were significant differences ($P < 0.05$) in the mineral composition of the PEMFT-SP (Table 3). Mineral composition (Ca, P and Zn), of PEMFT-SP were significantly higher than that of blanched samples, up to MFS (30.0mT) /PT(5.0Min). In addition, (Fe, and K) at MFS (13.20mT)/ PT(5.0Min) and MFS (24.0mT)/ PT(10.0Min) respectively had significantly higher values (0.65ppm and 40.40ppm) than blanched samples. These are indications of better protection against losses in blanching. The ranges of (Ca, P, Zn , Fe and K) were (18.57-27.56ppm), (3.99-6.76ppm), (0.69-1.39ppm), (0.47-0.65ppm) and (24.77-40.40ppm) respectively. This result is within the range of the values (25.29-49.64 Mg/100g) obtained by Armand *et al.,* (2012) on three varieties of onion and lower than the values (122-169 Mg/kg) recorded by Major *et al,* (2022) on shallot species. However, Bode *et al,* (2020) values (15.15 ppm) on food spices were lower compared to the values recorded in this research. Minerals are inorganic elements that are obtained from the diet and cannot be synthesised in the body. Although minerals are not macronutrients, they are quite necessary for the maintenance of normal biochemical processes in the body (Odebunmi *et al.,* 2010: Zhao *et al.* 2016: Armand, 2018). The deficiency of such nutritionally essential minerals usually proves lethal (Odebunmi *et al.,* 2010). The result of the mineral composition indicates that PEMFT-SP samples retained their mineral content except sodium which reduced as the value of the MFS increased. Hence, PEMF treatment is particularly suitable for mineral composition retention as compared to blanching.

Table 3: Mineral composition of PEMFT-SP influenced by MFS and PT

Samples	MFS (mT)	PT (mins)	Na (ppm)	K (ppm)	Ca (ppm)	P (ppm)	Fe (ppm)	Zn (ppm)
NAS	8.00	25	$31.49{\pm}0.03^{c}$	$24.77{\pm}0.12^{e}$	$24.37{\pm}0.06^{c}$	4.55 ± 0.01^{e}	0.47 ± 0.00^{e}	1.24 ± 0.00^{b}
ESO	13.50	20	$26.84{\pm}0.07^{f}$	$36.30{\pm}0.28^{b}$	$20.56{\pm}0.06^{e}$	4.96 ± 0.00^{d}	0.61 ± 0.01^{a}	1.09 ± 0.00^{c}
FUL	19.00	15	$30.87{\pm}0.16^{d}$	$36.48{\pm}0.08^{b}$	$26.13{\pm}0.12^{b}$	5.52 ± 0.00^{c}	0.52 ± 0.02^{c}	0.85 ± 0.00^{d}
KAZ	24.00	10	$33.13{\pm}0.06^{b}$	$40.40{\pm}0.01^{a}$	$18.57{\pm}0.12^{f}$	6.07 ± 0.06^{b}	0.38 ± 0.00^{f}	0.86 ± 0.00^{d}
TON	30.00	5	$28.52{\pm}0.03^{e}$	$35.75{\pm}0.12^{c}$	$27.56{\pm}0.06^{a}$	6.76 ± 0.01^{a}	0.54 ± 0.01^{b}	1.39 ± 0.01^{a}
ELA	NIL	NIL	$37.27{\pm}0.24^{a}$	$30.55{\pm}0.05^{d}$	$23.07{\pm}0.06^{d}$	3.99 ± 0.00^{f}	0.49 ± 0.00^{d}	0.69 ± 0.00^{e}

Means with the same superscript in the same column are not significantly different ($P < 0.05$)
MFS: Magnetic Field Strength: PT: Pretreatment Time

Antioxidant Capacity of PEMFT-SP as influenced by MFS and PT

The antioxidant composition of the PEMFT-SP samples was significantly higher ($p < 0.05$) than the control (Table 4). The values of the antioxidant power, Total phenolic content and Total flavonoids ranged between 27.73-28.51 Mg/g, 12.44-13.46 Mg/g and 0.27-0.47 Mg/g respectively. Sample ESO, treated with MFS of 13.50 for 20minutes exhibited the best antioxidant properties. Similar results on total phenol and flavonoid were reported by Odewole *et al,* (2022) for magnetic field treated sweet peppers and Vishki *et al,* (2012). This implies that pulsed electromagnetic field pretreatment performs better at retaining antioxidants than blanching, a convectional and thermal processing method. Antioxidants inhibit the process of oxidation, even at moderately small concentrations and therefore have various physiological roles in the body (Yadav *et al.,* 2016).

Table 4: Antioxidant capacity of PEMFT-SP as influenced by MFS and PT

Samples	MFS (mT)	PT (mins)	Antioxidant Power (Mg/g)	TPC (Mg/g)	Total Flavonoid (Mg/g)
NAS	8.00	25	28.15 ± 0.02^{b}	13.11 ± 0.02^{b}	0.32 ± 0.00^{bc}
ESO	13.50	20	28.51 ± 0.06^{a}	13.46 ± 0.07^{a}	0.47 ± 0.01^{a}
FUL	19.00	15	27.99 ± 0.02^{c}	12.86 ± 0.03^{e}	0.30 ± 0.00^{d}
KAZ	24.00	10	28.08 ± 0.01^{bc}	13.00 ± 0.02^{c}	0.32 ± 0.01^{b}
TON	30.00	5	28.03 ± 0.01^{c}	12.93 ± 0.03^{d}	0.31 ± 0.00^{c}
ELA	NIL	NIL	27.73 ± 0.01^{d}	12.44 ± 0.03^{f}	0.27 ± 0.00^{e}

Means with the same superscript in the same column are not significantly different ($P < 0.05$)
MFS: Magnetic Field Strength PT: Pretreatment Time; TPC: Total Phenolic Content

Anti-nutritional Properties of PEMFT-SP influenced by MFS and PT

The anti-nutrients level in the PEMFT-SP samples differed significantly (p<0.05) from the control with a steady increase in the MFS and PT values (Table 5). The oxalate content ranged between(6.89 and 17.97 mg/g) with FUL (19MFS:15PS) having the highest value and ELA (Control) the least value. The phytate content ranged between 12.77 and 16.32 Mg/g while Tannin content ranged between 1.98 and 2.20 Mg/g with a slight increase as the MFS values increased. Consequently, it can be inferred that PEMF treatment is not very effective in reducing these antinutrients, irrespective of the MFS and PT. Excessive consumption of unprocessed phytate, can impede mineral absorption. Tannins are phenolic compounds that attach to metal ions during digestion, rendering them unavailable. (Herremans *et al*, 2020).

Table 5: Anti-Nutritional Properties of PEMFT-SP influenced by MFS and PT

Samples	MFS (mT)	PT (mins)	Oxalate (mg/g)***	Phytate (mg/g)***	Tannin (mg/g)***
NAS	8.00	25	8.50 ± 0.14^{d}	$12.77 \pm O.41^{c}$	2.08 ± 0.01^{c}
ESO	13.50	20	9.42 ± 0.05^{c}	11.54 ± 0.01^{d}	2.20 ± 0.01^{a}
FUL	19.00	15	17.97 ± 0.28^{a}	14.50 ± 0.43^{b}	2.02 ± 0.01^{d}
KAZ	24.00	10	10.08 ± 0.15^{b}	16.19 ± 0.47^{a}	2.16 ± 0.01^{b}
TON	30.00	5	9.22 ± 0.05^{c}	16.32 ± 0.87^{a}	2.03 ± 0.01^{d}
ELA	NIL	NIL	6.89 ± 0.14^{e}	14.04 ± 0.05^{b}	1.98 ± 0.01^{e}

Means with the same superscript in the same column are not significantly different (P < 0.05)
MFS: Magnetic Field Strength PT: Pretreatment Time; TPC: Total Phenolic Content

Sensory Attributes of Smoked Meat Spiced with PEMFT-SP influenced by MFS and PT

All samples were generally accepted by the sensory panellists (Table 6) for all parameters on nine-point hedonic scale. Appearance ranged between (5.17 - 6.97), Taste (5.20-6.67), Aroma (5.40.6.33), Aftertaste (5.53-6.67) and Overall acceptability (6.03-7.40). All PEMFT-SP samples compared favourably with the blanched and ELA(control). However, PEMF-treated SP at MFS 24.00mT for 10mins was most preferred among the samples by the panelists.

Table 6: Sensory Properties of Smoked Meat Spiced with PEMFT-SP as influenced by MFS and PT

Sample	MFS (mT)	PT (mins)	Colour	Taste	Aroma	After taste	O.A
NAS	8.00	25	5.97 ± 1.33^{cd}	6.67 ± 1.27^{a}	6.33 ± 1.40^{a}	6.37 ± 1.16^{a}	6.93 ± 1.11^{ab}
ESO	13.50	20	6.70 ± 1.15^{ab}	6.33 ± 1.09^{ab}	6.17 ± 1.18^{ab}	6.23 ± 0.90^{ab}	7.07 ± 1.01^{ab}
FUL	19.00	15	5.73 ± 1.26^{cde}	5.80 ± 1.06^{bc}	5.77 ± 1.10^{abc}	5.67 ± 1.09^{bc}	6.53 ± 0.86^{bc}
KAZ	24.00	10	6.97 ± 1.30^{a}	6.57 ± 1.43^{a}	6.33 ± 1.32^{a}	6.67 ± 1.12^{a}	7.40 ± 1.07^{a}
TON	30.00	5	5.17 ± 1.46^{e}	5.37 ± 1.25^{c}	5.53 ± 1.25^{bc}	5.57 ± 1.14^{bc}	6.00 ± 1.20^{c}
ELA	Blanched	Blanched	6.17 ± 1.32^{bc}	6.43 ± 1.28^{ab}	5.67 ± 1.35^{abc}	6.23 ± 1.33^{ab}	6.57 ± 1.48^{bc}
OSF	NIL	NIL	5.37 ± 1.30^{de}	5.20 ± 1.54^{c}	5.40 ± 1.61^{c}	5.53 ± 1.72^{c}	6.03 ± 1.90^{c}

Means with the same superscript in the same column are not significantly different (P ≤ 0.05)
MFS: Magnetic Field Strength; PT: Pretreatment Time ; OA: Overall Acceptability

CONCLUSION AND RECOMMENDATIONS

PEMF-treated SP at varying MFS and PT exhibited better protection of the chemical composition (vitamins C, B6 and A; potassium, calcium, phosphorus, iron and zinc), antioxidant properties (antioxidant power, total phenolic content and total flavonoid), and sensory attributes of shallot powder than blanching. The content of anti-nutrient (oxalate and tannin) in PEMF-Treated shallot powder was also in comparison with that of blanched samples. PEMF-treated SP at MFS 24.00mT for 10mins was most preferred among the samples by the panelists. Therefore, PEMF-pretreatment of shallot should be encouraged. Studies on optimisation of MFS and PT for

PEMF-treatment of shallot or similar species are recommended.

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Authors' Contributions

KKO, FRF, AIL & FSO managed data collection, interpretation of data, writing of manuscript, material support, and review of manuscripts and wrote the first draft of the manuscript. AIL, MS and FRF. managed the literature searches. KKO, FSO and MS managed the development of methodology, data analysis, and the development of the model. All authors read and approved the final manuscript.

Ethics Statement

Not applicable.

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