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Effects of Treatment Time and Magnetic Field Strength on Functional and Physical Properties of Shallot (*Allium Ascalonicum L.*) Powder Treated with Electromagnetic Field

Olatoye[1]*, K. K., Alabi[2], K. P., Lawal[3], A. I., Oyeniyi[1], F. S. and Adeyemo[4], O. I.

[1]Department of Food Science and Technology,
Faculty of Agriculture, Kwara State University Malate, P.M.B.1530, Ilorin, Nigeria
[2]Department of Food and Agricultural Engineering,
Faculty of Engineering and Technology, Kwara State University Malate, P.M.B.1530, Ilorin, Nigeria
[3]Department of Food Science and Technology,
Faculty of Engineering and Technology, Abiola Ajimobi Technical University, Ibadan, Nigeria
[4]Department of Food Science and Technology, Faculty of Food Science
Ladoke Akintola University of Technology, Ogbomoso, Nigeria

**Corresponding author: luckykaykay@yahoo.com (08034266852)*

Abstract

Shallot, an allium species valued for their aromatic and functional properties, are prone to quality loss during processing. The effects of magnetic field strength and treatment time on functional and physical properties of electromagnetic field treated shallots powder was evaluated in this study. Shallot bulbs were treated at different MFS (8.00 to 24.00mT) and PT (5 to 25 minutes) using PEMF devices. 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 functional and physical properties such as oil absorption capacity, water absorption capacity, solubility index, and bulk density using standard methods. The results showed that oil absorption capacity, water absorption capacity, and solubility index of PEMFT-SP had the highest values at 19.00mT for 15 minutes which was significantly higher than the control indicating enhanced rehydration and flavour retentions. However, swelling capacity was highest in the control sample, suggesting differences in starch content. Colour intensity varied slightly, with the PEMF-treated samples maintaining acceptable lightness (L values) without significant changes in redness (a*) or yellowness (b*). These findings suggest that PEMF pretreatment is a viable non-thermal method for preserving and enhancing the functional properties of shallot powder. However, studies on optimization of PEMF parameters for broader applications in spice and vegetable processing are recommended.*

***Key words**: Food pretreatment, Food seasoning, Shallot , Spices. colour intensity.*

Introduction

Thermal treatment in food processing and preservation is regarded as most effective and cost-effective technologies apart from their minimal technical-know-how requirements (Olatoye *et al.,* 2024). However, the use of thermal processing can lead to undesirable

alterations in food physical attributes, particularly the colour and functional properties, together with possible loss of nutritional values and sensory attributes of the final products (Chauhan and Unni, 2015). Exploration of non-thermal processing technologies with their remarkable minimal impact on food components, physical and functional characteristics coupled with their product prolonged shelf-life extension tendencies becomes a *sine qua none* (Zhao *et al*., 2019: Olatoye *et al.,* 2024). A lot of research works on the impacts of non-thermal technologies as alternatives in food processing and preservation have therefore been documented. Research have been diversely conducted on the utilization of non-thermal pretreatment techniques like High Hydrostatic Pressure (HHP), irradiation, pulsed light, ultrasonics, pulsed X-rays, and the application of magnetic fields such as Pulsed Electromagnetic Field (PEMF) (Neeto and Chen, 2014: Zhao *et al.,* 2019: Oduwole *et al.,* 2022). Pulsed Electromagnetic Field (PEMF) technology was described as the one involving creating and directing pulsed electromagnetic waves towards either a liquid or a semi-solid food situated in-between two electrodes. The resulting waves will then interact with the cells they contact, leading to alteration of the state of the electron's spin system (Pawluk, 2015: Takaki *et al.,* 2021). Essentially, its operating principle relied on the principles of electromagnetism, where a magnetic field is produced only when electric current flows through a wire wound around a core. Up till now, there is dearth of studies on the impact of PEMF technology on food items like spices; despite its versatility and potentials as a promising non-thermal method for reducing microorganisms, nutrient retention, and preservation of physical, sensory and functional properties of food and biological materials (Dimitrakellis *et al.,* 2020; Seyfali *et al.,* 2024). Its application in spice processing may result in development of value-added products with strong commercialization prospects.

Conventionally, spices have been recognised as aromatic parts of plants, such as tree-bark, flowers, buds, fruits, rhizomes, seeds, leaves, roots, stigmas, and styles, which are utilised to enhance the flavour, aroma, colour, and shelf stability of food and drink (Arachchige *et al.* 2021). As it is the common practice, spices are dried and used in their whole form or ground into powder for ease of use (Herman, 2015). The popularly used ones in Nigeria are ginger, pepper, onion, garlic and shallots. (Olatoye *et al.,* 2024).

Shallot (Allium ascalonicum L) as a type of horticultural product classified among spice vegetables and much like onions, domiciles in the allium family. It however different with marked stronger aroma and a more intense flavour (Sun, *et al.,* 2019). Shallots are reported to be grown in clusters of small bulbs and cloves and as key player in seasoning dishes to enhance flavour in addition to medicinal benefits inherent in it. Nutritionally, It was documented as rich source of carbohydrates, vitamins A, B, C, fibres, minerals, proteins, and phytochemicals like polyphenols (Sun *et al*., 2019; Sittisart *et al.,* 2017). Like many other vegetable spices, it is a highly perishable commodity and in order to enhance its shelf life and usability, shallots are often converted into powder (Kubec *et al.* 2018). Furthermore, shallots and other Allium vegetables tend to develop a bitter flavour when subjected to excessively high heat; this is caused by the production of Allithiolanes, which are a newly identified group of sulphur compounds linked to the unpleasant bitter taste in processed onions and other Alliums. The processing of shallots into powder can trigger an enzymatic browning reaction due to phenolic compounds, facilitated by polyphenol oxidase, which leads to undesirable colour and flavour changes as well as nutrient loss (Zhu *et al*., 2022; Moon *et*

al., 2020; Lante *et al.,* 2016). This may affect the quality of the shallot in terms of its functional properties such as swelling, dispersion and solubility apart from the discolouration (Filtzpatrick *et al,* 2016). Hence, it is essential to pretreat shallots prior to processing preferably with the use of non-thermal pretreatment methods such as Pulsed Electromagnetic Field (PEMF) Technology. The limited studies on PEMF have primarily concentrated on its effects regarding microbial inactivation in dairy products, juices, egg products, and other liquid foods, while there is scarce information on how this technology influences food constituents and overall quality and acceptability. Although, the Impact of this treatment method on chemical properties of shallot powder and sensory attributes of suya- meat product spiced with it had been recently documented (Olatoye *et al*., 2024). However, no report of the functional properties and colour intensity of the product as influenced Pulsed Electromagnetic Field (PEMF) treatment conditions have been documented. Therefore, the purpose of this study is to assess the influence of magnetic field strength and pretreatment time on the functional and physical (colour) properties of shallot powder.

Materials and Methods

Equipment such as a locally manufactured electromagnetic field pre-treatment device was used for shallot pretreatment at the Department of Food Engineering, Federal University of Technology, Akure, Ondo State. Other equipment includes, Portable electronic weighing balance, cabinet oven and desiccator which were also obtained from the same laboratory. Samples of freshly harvested shallots were obtained from mandate market Ilorin, Kwara State.

Pre-treatment of shallot bulbs and production of shallot powder

Cleaning activities such as sorting, washing, and cutting/slicing were carried out on the shallot bulbs. Thereafter, uniform experimental quantities per run (100g) was measured with the electronic weighing balance. The measured samples were 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 following the method of Odewole, *et al.,* (2022) (Table 1). The control sample was blanched by scalding the sliced shallot in boiling water at 80 to 100˚C for 5 to 10 minutes. Lastly, all pulsed-electromagnetic field pre-treated and blanched samples were dried in the cabinet drier at 60˚C (Fig.1.0) and briefly kept in the desiccator, to prevent moisture absorption.

Table 1: Selected PEMF strengths and Pretreatment Time (PT) of shallot powder.

Samples	Voltage (V)	MFS (mT)	PT (minutes)
NAS	3.20	8.00	25.00
ESO	5.00	13.50	20.00
FUL	6.60	19.00	15.00
KAZ	8.30	24.00	10.00
TON	10.10	30.00	5.00
ELA (control)	Nil	Nil	Nil

MFS – Magnetic Field Strength (mili Telsa): PT – Pretreatment Time
ELA (blanched at 80 to 100 ˚C for 5 to 10 mins)

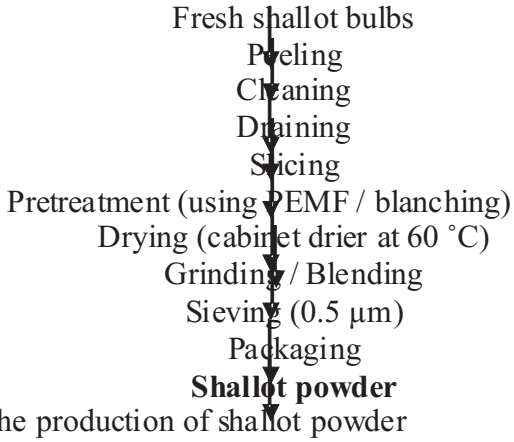


Fig. 1.0: Flow chart for the production of shallot powder
Source: Olatoye *et al.,* (2024)

Determination of Functional and physical Properties of PEMF-Treated and blanched Shallot Powder

Swelling power

This was determined according to the method described by Leach *et al.,*(1995) with modification for small samples. Weighed amount (0.1g) of powder sample was placed in a test tube into which 10ml of distilled water was added. The solution was heated in a water bath at temperature of 60 ˚C for 30 min and was continually shaken throughout the period of heating. Test tube was then centrifuge at 2200rpm for 15min, to aid the removal of the supernatant. This was then carefully decanted and the weight of the starch paste was determined. Calculation of swelling power was as shown in equation 1.

$$SP = \frac{\text{Weight of starch paste}}{\text{Weight of dry starch sample}} \quad \text{Eq. .1}$$

Bulk Density

The method of AOAC (2000) was used to determine the bulk density of shallot powder samples. The sample (7g) was weighed into a 50ml graduated measuring cylinder. The cylinder was tapped gently against the hand palm until a constant volume was obtained, and the bulk density (BD) calculated as shown in equation 2.

Results and Discussion

Functional properties of PEMFT-SP as influenced by MFS and PT

The functional properties of PEMFT-SP as influenced by magnetic field strength and pretreatment time are presented in Table 2.0. The oil absorption capacity (OAC) of the shallot powder samples ranges from 87.00 to 96.33 (%), with sample FUL being the highest while sample NAS the least. The OAC of FUL (96.33 %), (the sample treated with magnetic field strength of 19 **mT for 15 minutes)** was not significantly (P>0.05) different from that of ELA, that is, (blanched sample) which was 94 %. The result was quite lower than the values (2.60 - 3.60 (g/g) documented by Zubair, *et al.,* (2020), on the Oil absorption capacity of some local spices. This might be because of the pretreatment method used. Oil absorption capacity is defined as the difference in weight of the flour before and after oil absorption (Giami*et al.*,

1994). OAC is an essential functional property in food formulations, that contributes to enhancing mouth feel while retaining the food products' flavor (Iwe *et al.,* 2016). OAC gives an indication of flavour-retaining capacity of flour. Moreover, it is useful in structure interaction in food including shelf-life extension, particularly in bakery or meat products (Adebowale and Lawal 2003a). Hydrophobic proteins show superior binding of lipids, implying that non-polar amino acid side chains bind the paraffin chains of lipids (Kaur and Singh, 2005; Adejuyitan *et al*., 2009). Similarly, WAC of ELA (control sample) was (206.80 %) and was not significantly different from (WAC) of sample FUL, which was the highest (211.93%). Sample KAZ (192.87 %) possesses the least value of OAC. Generally, WAC values ranged from (192.87- 211.93%). Some of the results are slightly lower in comparison with results of earlier studies. However, others are still in accordance with 2.05 to 3.95 (g/g) documented by Zubair *et al.,* (2020), on the OAC of some local spices. Water absorption capacity of powder is defined as the differences in weight of the powder before and after water absorption (Abbey and Ibeh, 1988). It describes the affinity of the powder for water, under limited water supply. The rate of water absorption by the flour sample is dependent of water absorption capacity and this also will affect the rate at which the water granules swell during reconstitution of the flour. It implied here that **PEMFT-SP** at 19 **mT for 15 minutes** was not significantly ($P>0.05$) different from that of ELA, that is, sample that was blanched between 80 to 100 ˚C for 5 to 10 mins in both OAC and WAC. Significant differences ($P < 0.05$) exist in the swelling capacity (SC) of the shallot powder samples and the values range between 5.43 and 12.43 (%), with ELA (blanched sample) having the highest value and ESO (sample treated at 13.5mT for 20minutes) the lowest. The result recorded in this study is very low compared to the values (32.32 to 48.43 (g/g)) reported by Hye *et al.,* (2007), on the SC of onion powder as influenced by drying methods which might be due to a lower starch content in the shallot powder samples. The swelling index depends on the water intake of the flour which might have been influenced by pretreatment methods in this study. SC is an indication of the non-covalent bonding between the molecules of starch granules and also one of the factors of the α-amylose and amylopectin ratios (Iwe *et al.,* 2016). There were significant differences ($P<0.05$) between the samples in terms of their solubility index (SI) and the SI of the shallot powder samples ranged between (19.48 - 21.41%). Samples FUL (treated with 19mT for 15min) and KAZ (treated with 24mT for 10min) had the highest and the solubility index respectively. The result is lower than the values (55.77 to 66.20%) documented by Hye *et al.,* (2007) on the SI of onion powder as influenced by drying methods. It implied that the pretreatment conditions might have influenced SI of the SP accordingly. The relative reductions in SI could be attributed to variation in lipid contents between the pretreated and non-pretreated powders prior to drying.

The presence of lipids reduces water absorption capacity of foods (flours) which can lead to reduced swelling capacity and consequently reduced solubility (Oppong *et al*., 2015). Solubility serves as the most dependable indicator for assessing how well powders can dissolve and create a stable suspension in water (Chen *and* Patel, 2008). To achieve the intended functional properties in a food system during the rehydration process, shallot powder needs to engage with water. Significant differences ($P < 0.05$) exist

in the bulk density (BD) of the shallot powder samples pretreated at different magnetic field strength and duration. The values of BD ranged between (0.88 and 0.96 %), with FUL (treated at 19mT for 15min) having the highest value and KAZ (Treated at 24mT for 10min) the lowest. It shows that treatment of shallot at a lower magnetic field strength and longer time could provide a bulkier powder than treating it at a higher strength at a lesser period. In comparison with blanched sample, which is the control, the BD was (0.94%) and was not significantly from that of FUL (treated at 19mT for 15min) i.e. (0.96 %). This indicated that shallot treated at 19mT for 15min can efficiently compare with the one blanched prior to drying in terms of bulkiness. Zubair *et al.,* (2020), documented a lower range of 0.27 to 0.44 (g/mL) in some local spices. This might be due to the shallot powder samples' smaller particles. Higher bulk density is desirable as it provides greater packaging advantage, since greater quantity of flour may be packed within a constant volume (Ijarotimi and Ashipa, 2005). Bulk density is a measure of how heavy, is a flour sample (Oladele and Aina, 2007). In summary, sample of shallot powder pretreated with at 19.00mT for 15 mins possessed similar functional properties such as (OAC, WAC, SI, and BD) to that of blanched sample, but slightly inferior to it in terms of SC.

Table 2: Functional properties of PEMFT-SP as influenced by MFS and PT

MFS (mT)	*PT (mins)*	*OAC(%)*	*WAC(%)*	*SC(%)*	*SI(%)*	*BD(%)*
8.00	25	87.00 ± 3.61^{b}	197.27 ± 4.58^{bc}	6.47 ± 0.37^{b}	19.93 ± 0.46^{bc}	0.90 ± 0.02^{bc}
13.50	20	$93.00 + 1.00^{a}$	$204.60 + 2.20^{ab}$	$5.43 + 0.05^{c}$	$20.67 + 0.22^{ab}$	$0.93 + 0.01^{ab}$
19.00	15	$96.33 + 2.08^{a}$	211.93 ± 4.58^{a}	$5.77 + 0.21^{c}$	$21.41 + -0.46^{a}$	0.96 ± 0.02^{a}
24.00	10	87.67 ± 3.06^{b}	192.87 ± 6.72^{c}	5.64 ± 0.30^{c}	19.48 ± 0.68^{c}	0.88 ± 0.03^{c}
30.00	5	87.33 ± 4.62^{b}	198.73 ± 1.27^{bc}	5.73 ± 0.36^{c}	20.07 ± 0.13^{bc}	0.90 ± 0.01^{bc}
BL	CR	94.00 ± 1.00^{a}	206.80 ± 2.20^{a}	12.43 ± 0.34^{a}	$20.89 \pm o.22^{a}$	0.94 ± 0.01^{a}

Means with the same superscript in the same column are not significantly different (P = 0.05)
MFS: Magnetic Field Strength
PT: Pretreatment Time
ELA (blanched at 80 to 100 °C for 5 to 10 mins): BL(blanching) and CR (control).

3.6. Colour intensity of PEMFT-SP as influenced by MFS and PT

Colour intensity of shallot treated at different magnetic field strength and duration varied significantly (P<0.05) (Table 3). L-values (lightness) ranged between (31.66 and 32.69), with ESO (sample treated at 13.5mT for 20 minutes) being the lightest (32.69) followed by KAZ (32.49), ELA (32.13), NAS (32.02), TON (31.76) and FUL (31.66). This trend indicated a preference of lesser magnetic field strength for lightness of the shallot pretreatment. However, KAZ (sample treated at 24 mT for 10 minutes) was not significantly different from ESO in lightness, implied that lesser treatment time with higher magnetic field strength can equally yield same result. This is in accordance with the values (20.06 to 80.09) documented by Armand *et al.,* (2012) on some wild plants used as spices in Cameroon and Armand *et al.,* (2018) on three varieties of onion. However, it was lower than the values (70.68-90.91) reported by Hye, *et al.,* (2007), on physicochemical properties of onion powder as influenced by drying methods**.** The a-values (red/green values) of shallot treated at different magnetic field and time were not significantly (P>0.05) different from that of blanched samples and ranged between (0.16 and 0.32). NAS **(treated at**

8mT for 25mins) had the highest redness value (0.32), while KAZ (treated at 24mT for 10mins) possessed the lowest (0.16) redness value. This implies that lesser field strength is preferrable to higher ones to obtain reddish shallot power. Similar trend was observed in terms of "b" (blue / yellow value) except for sample ESO as presented in Table 7. The b-values ranged between (3.01-3.33) with samples TON (treated at 30mT for 5mins) and ESO (treated at 13.5 for 20mins) being the highest and the lowest respectively. The b-values (yellow/blue values) of shallot treated at different magnetic field and time were not significantly (P>0.05) different from that of blanched samples, except ESO (treated at 13.5 for 20mins). It implied here also that pretreatment of shallot with electromagnetic field required careful selection of magnetic field strength and treatment time. Sample KAZ (treated at 24mT for 10mins) can be regarded as the best for the colour attributes (L, a and b) and can thus be suggested as a suitable replacement for blanching of shallot for colour preservation. In summary, it can be inferred that 24.00mT for 10.00mins is the most suitable condition for PEMF treatment of shallot in order to retain the colour intensity better than that of blanched pre-treated sample in the production of shallot powder.

Table 3: Colour intensity of PEMFT-SP as influenced by MFS and PT

Samples	MFS (mT)	PT (mins)	L***	a (NS)	b*
NAS	8.00	25	32.02 ± 0.26^{b}	0.32 ± 0.24^{a}	3.21 ± 0.23^{a}
ESO	13.50	20	32.69 ± 0.08^{a}	0.30 ± 0.12^{a}	3.01 ± 0.06^{b}
FUL	19.00	15	31.66 ± 0.03^{c}	0.17 ± 0.05^{a}	3.29 ± 0.04^{a}
KAZ	24.00	10	32.49 ± 0.08^{a}	0.16 ± 0.14^{a}	3.22 ± 0.06^{a}
TON	30.00	5	31.76 ± 0.04^{c}	0.30 ± 0.06^{a}	3.33 ± 0.02^{a}
ELA	Blanched	Control	32.13 ± 0.10^{b}	0.23 ± 0.04^{a}	3.32 ± 0.07^{a}

Means with the same superscript in the same column are not significantly different ($P \leq 0.05$)
MFS: Magnetic Field Strength
PT: Pre-treatment Time
ELA (blanched at 80 to 100 ˚C for 5 to 10 mins)

Conclusions

The influence of magnetic field strength (mT) and Time (mins) on the functional and physical properties of pulsed electromagnetic field treated-shallot powder was documented in this study. The study revealed that, with exception of swelling capacity (SC), sample of shallot powder pretreated with 19.00mT for 15 mins possessed similar functional properties such as (OAC, WAC, SI, and BD) to that of blanched sample. However, treatment condition 24.00mT for 10.00mins appeared the most suitable condition for PEMF treatment of shallot to retain the colour intensity better than that of blanched pre-treated sample in the production of shallot powder. Further studies are recommended to optimize MFS and PT for PEMF treatment and extend this research to other spices and food product development to maximize the benefits of this novel technology.

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Data Availability

All data used are included in the manuscript.

Conflicts of Interest

The authors declare that there is no conflict of interest.

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Table 9: Effect of NPK fertilizer and poultry manure on LER of maize/castor cropping systems in Ogbomoso

	Year 2
Fertilizer treatments	
Control	2.02
NPK 120- 60-30 kg/ha	2.75
Poultry manure	1.55
Combined NPK + PM	2.34

PM-Poultry manure

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