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MICROSTRUCTURAL CHARACTERISTICS AND ELEMENTAL DISTRIBUTION OF MAGNETIC FIELD PRETREATED SWEET PEPPER

Michael M. Odewole[1✉], Ayoola P. Olalusi[2], Olufunmilayo S. Omoba[3], Ajiboye S. Oyerinde[4]

[1]*Department of Food Engineering, Faculty of Engineering and Technology, University of Ilorin, Nigeria*
[2, 4] *Department of Agricultural and Environmental Engineering, Federal University of Technology Akure, Nigeria.*
[3]*Department of Food Science and Technology, Federal University of Technology Akure, Nigeria.*
✉*odewole2005@yahoo.com*

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ABSTRACT

The impact of magnetic field (non-thermal) pretreatment on the microstructures and elemental distribution of sweet pepper was studied. Static and pulse magnetic fields (SMF and PMF) were used in combination with magnetic field strength (8 – 30 mT) and pretreatment time (5 – 25 min) for the study. Blanching (thermal) pretreatment was used as the control. After the pretreatment, all samples were dried at 50 ºC and were analyzed with Scanning Electron Machine (SEM) for microstructures and elemental distribution. Results revealed that, generally, SMFs exhibited undetached outlooks unlike PMFs that are more of visible segregated microstructures. Specifically, SMF – 1 (8 mT & 5 min), PMF – 1 (8 mT & 5 min), SMF – 2 (19 mT & 15 min), PMF – 2 (19 mT & 15 min), SMF –3 (30 mT & 25 min), PMF – 3 (30 mT & 25 min), blanched and fresh samples showed fine spongy, segregated pebbles, partially wrinkled and undetached, bigger sizes of irregular segregated, somewhat eroded surface, smaller sizes of irregular surface with some visible holes, roughened appearance with different sizes of clumps and large puffs with dots of small particles microstructures respectively. Furthermore, the elemental analysis established that magnetic field pretreatment at PMF – 2, PMF – 3, PMF – 1 and SMF – 2 led to significant improvement/better retention in values of most elements (Na, Ca, Mg and P) considered than blanched and fresh samples at 5% probability level.

1.Introduction

Sweet pepper (SP) - (*Capsicum annum*) is a fruit vegetable which is also known as bell pepper. It contains vitamin C, vitamin A, vitamin B and other nutrients in addition to low calorie. Sweet pepper is effective against cataracts, rheumatism, arthritis, lung cancer, diabetes, fever, cold, sores and bruises. Also, it helps in controlling the cholesterol level of human body and stimulates stomach secretion for the enhancement of food digestion (Odewole and Olaniyan, 2016).

Pretreatment is one of the unit operations in food processing value chain that is done to ensure that foods are microbiologically safe for consumption, as well as improving their sensory, nutritional and functional attributes. Also, it can aid further processing of food and extend their storage life. Food pretreatment/processing methods can be broadly grouped into two, these are conventional and non-conventional methods (Neeto and Chen, 2014). The conventional method can also be referred to as traditional or common method. Some typical examples of conventional methods are: blanching, thermal pasteurization, thermal sterilization, parboiling, salting and manual size reduction. Non-Conventional method is also known as emerging or novel method because it is still evolving and its use is not as popular or common as the conventional method. High Hydrostatic Pressure (HHP), Pulsed Electric Field (PEF), irradiation, pulsed light (Neeto and Chen, 2014), sous vide, microwave heating, ohmic heating and the use of magnetic field are some the examples of the non-conventional method.

The aforementioned statements revealed that both methods of food pretreatment have thermal and non-thermal examples. The non-thermal category preserves the nutritive values of food and has the tendency of reducing the microbiological threats to food (Lipiec *et al*., 2004); whereas, the thermal category may lead to adverse depletion of some heat sensitive nutrients of food. Barbosa-Canovas *et al*. (2005) reported that emerging non-thermal technologies of food pretreatment aim at producing food of better quality than heat-treated foods. It also has the advantages of food processing cost reduction and food value addition characteristics.

Pretreatments can modify the microstructures of food; this can lead to consequential effects on some other properties (nutritional, sensory, functional, physical and mechanical) of food. Heertje (1993) stated that microstructural studies assist in establishing the relationship that exists in the composition, processing and final properties of many food products. Some recent works and vital information exist on the microstructures of foods (Rejaul et al., 2018; Verboven et al., 2018a; Fazaeli et al., 2012; Verboven et al., 2018b; Oladejo et al., 2017a; Oladejo et al., 2017b; Troncoso and Aguilera, 2009; Askari et al., 2004; Antonio et al., 2008; Gudmundsson and Hafsteinsson, 2001; Castro-Giraldez et al., 2011).

Electromagnetism is the concept that leads to the generation of magnetic field due to the flow of current in a conductor (wire) that is either wound or not wound around a core. Electromagnets are temporary magnets; which means, magnetic force can only be felt when current is flowing through the wire. Magnetic fields are classified according to their relative strength as low or high intensity; according to the variation of intensity over space as homogeneous or non-homogeneous; and over time as static or pulsed (Kovacs et al., 1997). The basic theory governing magnetic treatment of food materials could be adapted from the point of view of Dhawi et al. (2009). It was stated that living cells (food inclusive) have charges (in scattered form) which act as endogenous magnets. The endogenous magnets can be affected by exogenous magnet of an external magnetic field (from permanent magnet or electromagnet). This interaction would cause the naturally unpaired or scattered charges present in the internal part of the food materials to be rearranged in another pattern depending on factors such as: type of magnetic field, intensity of the magnetic field (MF), residence time of the product within the magnetic field and inherent characteristics of the food products. Furthermore, it is to be noted that biological membranes used to display strong orientation in magnetic field and cellular tissues are mostly affected by the application of magnetic field (Ordonez and Berrio, 2011). Ions in the cells of living things are responsible for the transmission of the effects of the MF to various parts of the materials.

Some available literatures on the use of magnetic field for food processing are Jia et al. (2015), Hayder et al. (2015); Lipiec et al., (2004); Ordonez and Berrio (2011); Ibara et al., (2015) and Kyle (2015). In all the few available literatures on the use of magnetic field for food pretreatment, microstructural studies and elemental distribution of pretreated foods were not considered. Hence, this study investigates the impact of two types of magnetic fields-Static Magnetic Field (SMF) and Pulse Magnetic Field (PMF), magnetic field strength and pretreatment time on the microstructure and elemental distribution (sodium – Na, potassium – K, calcium – Ca, magnesium – Mg and phosphorus – P) of sweet pepper. This research exposed other useful areas of application of magnet and established a strong basis for further research works in the use of magnet for food processing.

2. Materials and methods

2.1. Materials

The following materials and equipment were used: a magnetic field pretreatment device, electronic weighing balance (OHAUS, Model 201, China), laboratory oven (Model SM9053, England), desiccator, stainless steel knife and tray, Scanning Electron Machine (JEOL, JSM-7600F, Japan) and fresh samples of sweet pepper.

2.2. Sample Preparation

Fresh samples of sweet pepper were washed, cut with a stainless-steel knife, deseeded, measured (100 g) with the electronic weighing balance and pretreated in the magnetic field device. Two types of magnetic field (SMF and PMF) were used in combination with magnetic field strengths in the range 8 – 30 mT and pretreatment time (5 – 25 min). Blanched samples of sweet pepper were used as the control pretreatment. After the pretreatment operation, all samples were immediately dried at 50 ^{o}C inside the laboratory oven, packaged properly and briefly kept inside the desiccator after drying. The pretreatment experiment took place at the laboratory of the Department of Food Engineering, Faculty of Engineering and Technology, University of Ilorin, Ilorin, Nigeria in December 2018. The average temperature and average relative humidity of the laboratory during the drying of all samples were 32 ^{o}C and 63% respectively. After drying, all samples were taken for microstructural analyses on the Scanning Electron Machine (SEM) with the inclusion of Energy Dispersion X-ray (EDX) for elemental distribution.

3.Results and discussions

3.1. Microstructural Characteristics of Magnetic Field Pretreated Sweet Pepper (SP)

The microstructural characteristics of SP under SMF and PMF with different combinations of magnetic field strength and time of pretreatment; and in comparison, with blanched and fresh (untreated) samples are shown in Figures 1(a – d). The microstructures revealed that the applied SMF and PMF under same and different combinations of field strength and pretreatment time led to clear differences in the microstructures of SP. The blanched and fresh samples exhibited microstructural features that are distinctly different from those of the MF pretreated samples.

Generally, there is clear distinction between the microstructures of SMF and PMF pretreatment combinations. SMFs exhibited undetached outlooks unlike PMFs that are more of visible segregated microstructures. The possible reasons for the noticed differences could be attributed to the distinct characteristics of SMF and PMF. SMF is from fully rectified alternating current (AC) to direct current (DC), it has no frequency (Bird, 2010); therefore, its impact on the pretreated product is continuous. On the other hand, PMF is from partially rectified AC to DC (Bird, 2010), as result, it has a non-continuous (pulsating) impact on the pretreated product. The pulsating effect of PMF might have led to the introduction of repeated doses of stress at specific time intervals on the products which most likely caused the noticed segregated microstructures.

Specifically, SMF-1 (8 mT & 5 min) has fine spongy microstructure, PMF-1 (8 mT & 5 min) has microstructure that looked like segregated pebbles of different sizes, SMF-2 (19 mT & 15 min) has partially wrinkled undetached microstructure, and PMF-2 (19 mT & 15 min) shows bigger sizes of irregular segregated microstructure. Furthermore, SMF-3 (30 mT & 25 min) has somewhat eroded surface microstructure, PMF-3 (30 mT & 25 min) has smaller sizes of irregular microstructure with some visible holes. Finally, blanched sample shows a microstructure roughened with different sizes of clumps; the fresh sample shows large puffs with dots of small particles. The implications of the different microstructures could mean there would be better retention/improvement of available nutrients in the pretreated sweet pepper or otherwise; fast or slow drying rates; better or poor texture, sensory and functional properties.

The microstructural characteristics obtained in this study are in agreement with previous findings in some cases and not in agreement in others. For instance, Vodal et al., (2012) reported that only blanching pretreatment was unable to affect pore size distribution of freeze dried winter carrot, but more pores were achieved when blanching was combined with fast freeze drying. Otero et al. (2000) discovered that the microstructures of peach and mango fruits were maintained to a great extent after using histological techniques to analyze the modification done to their microstructures. Damage was not done to the microstructure of dried osmo-pretreated apple slices, but increase in porosity was achieved (Askari et al., 2004). Modification in terms of formation of pores within the microstructure (tissue) of dried osmo-pretreated sweet potato was achieved (Antonio *et al*., 2008). Pretreatment with distilled water and ultrasound of 28 kHz for maximum of 60 min did not cause significant effect on the microstructure of sweet potato slices of 3 mm thickness, whereas, the combined effect of the ultrasound pretreatment and osmotic dehydration with sucrose solution of 35 % (w/v) led to highest effect on the microstructure of the product (Oladejo et al., 2018b). The microstructures of fried sweet potato showed that ultrasound pretreatment before frying led to lesser uptake of oil (a positive effect) than sweet potato not pretreated (Oladejo et al., 2018a). Also, the combined effect of Pulse Electric field (PEF) and high pressure (200 – 300 MPa) caused more adverse effect on the microstructure of chicken meat, salmon and roes than PEF alone (Gudmundsson and Hafsteinsson, 2001). The modification effect on extracellular spaces of the microstructure of kiwi fruits pretreated with osmotic solution led to liquid occupying those spaces, whereas, air filled the extracellular spaces of fresh (untreated) kiwi fruit (Castro-Giraldez et al., 2011).

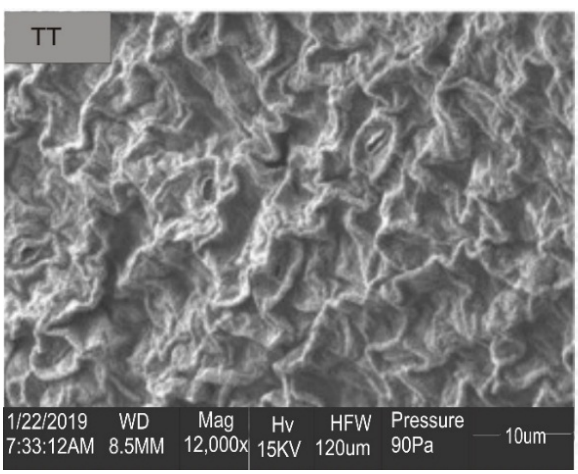

Figure 1a (i): Microstructure of SP at SMF-1

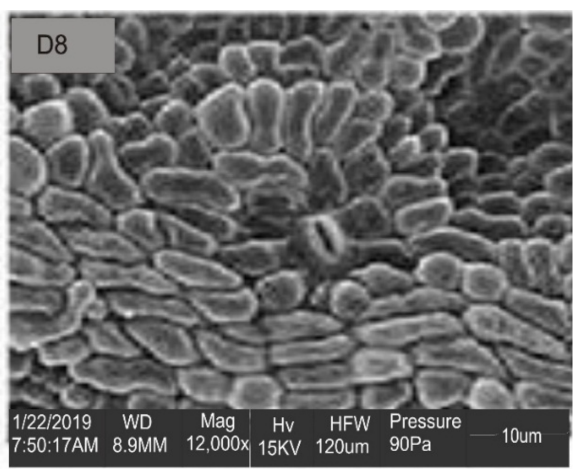

Figure 1a (ii): Microstructure of SP at PMF-

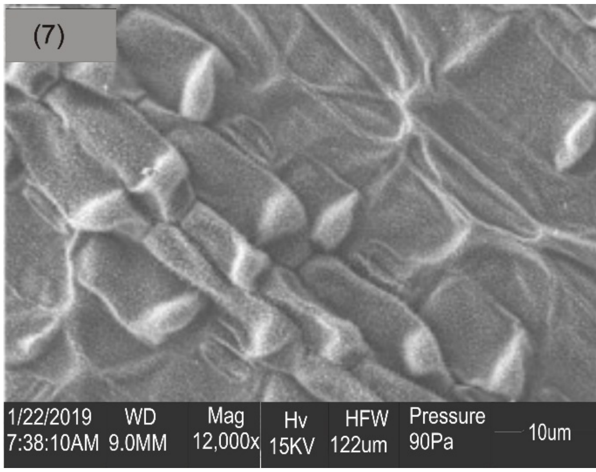

Figure 1b (i): Microstructure of SP at SMF-2

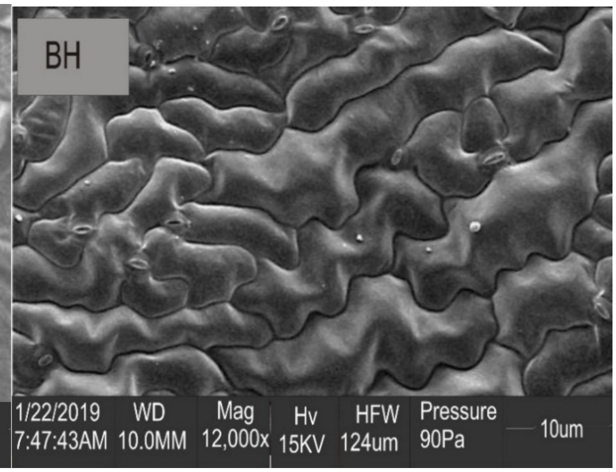

Figure 1b (ii): Microstructure of SP at PMF-2

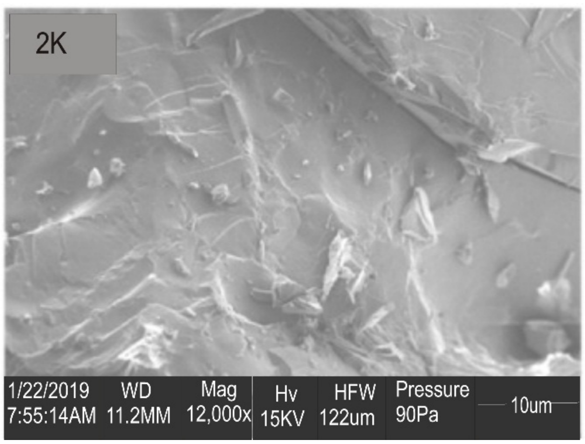

Figure 1c (i): Microstructure of SP at SMF-3

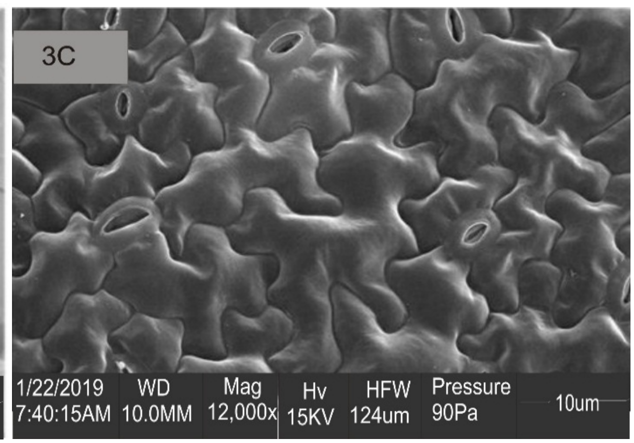

Figure 1 c (ii): Microstructure of SP at PMF-3

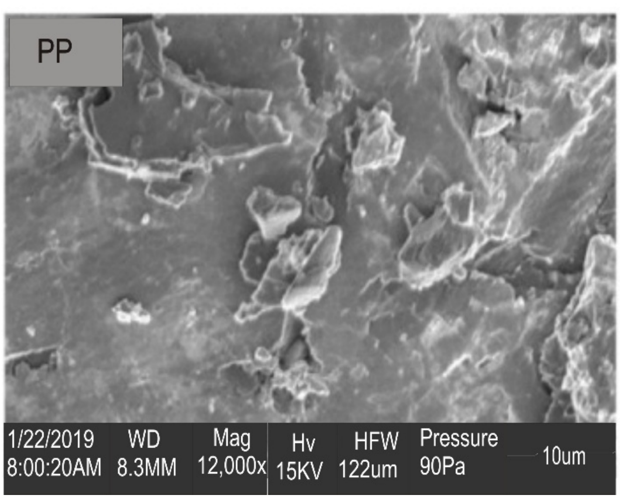

Figure 1d (i): Microstructure of SP for blanched

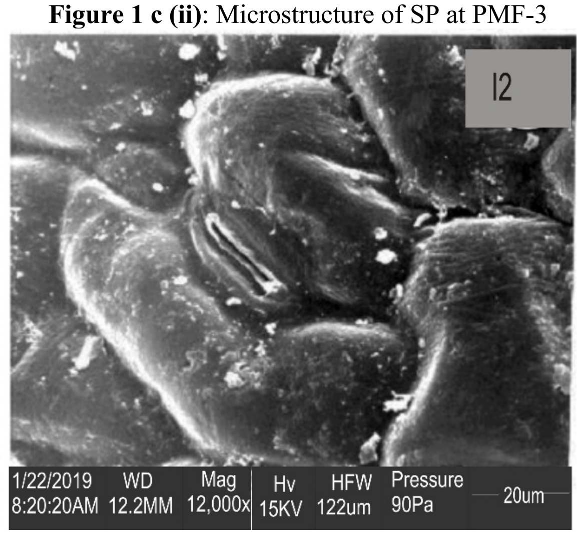

Figure 1d (ii): Microstructure of SP for fresh

3.2. Elemental Distribution of Magnetic Field Pretreated Sweet Pepper (SP)

Figures 2 (a – e) show the elemental distribution of magnetic field pretreated, blanched and fresh samples. The figures present a better understanding of the effect of pretreatments on sweet pepper in the sense that, they quantify the effects of pretreatments on the microstructure by showing different percentages of some elements (Na, K, Ca, Mg and P) present in the product. Also, the figures show the statistical implications of differences noticed among the elements analyzed at 5% probability value. This is indicated with the error bars (I) on each bar representing different pretreatment combination. From the figures, Na values at PMF-2 (2.20%) and PMF-3 (2.20%) are significantly higher than the values obtained for blanched (1.15%) and fresh (1.15%) samples. However, the lowest value of 0.25% for Na is at SMF-2. Also, blanched and fresh samples of SP have same value of 48.80% for K; this value is significantly higher than values obtained at PMF-2 (37.60%) and PMF-3 (35.60%), but not significantly higher than other magnetic field pretreatment combinations. For Ca, 30.30% and 33.00% were obtained at PMF-2 and PMF-3 respectively. These values are significantly higher than 24.22% and 23.14% obtained for blanched and fresh samples respectively. Furthermore, PMF-2 has 12.80% Mg which is only significantly higher than 10.80% obtained each for the blanched and fresh samples. Lastly, SMF-2 has 12.15% of P, and this value is significantly higher than 8.03% and 8.60% present in blanched and fresh samples and other magnetic field pretreatment combinations.

The possible reasons for the variations in elemental distribution might be due to some of the reasons earlier stated under the microstructural characteristics discussion. Also, it might be due to the fact that each element has its own unique characteristics in terms of type bond with other elements, strength of bond and arrangement of their structures within the sweet pepper. As a result, different behavior might be exhibited by each of them when sweet pepper is subjected to magnetic field pretreatment of different types of field (SMF or PMF) with different magnetic field strength and pretreatment time or other types of pretreatment. This might cause chemical reactions leading to adjustment in the values of elements above or below the natural values in the fresh samples. The observations in this study is within the report of Dhawi *et al.,* (2009) that the seedlings of date palm pretreated with static magnetic field strength (10 – 100 mT) for 30 – 360 min showed increase in the concentrations of Ca, Mg, Na, K; however, phosphorus (P) concentration dropped with increase in SMF strengths and time of exposure to the magnetic field.

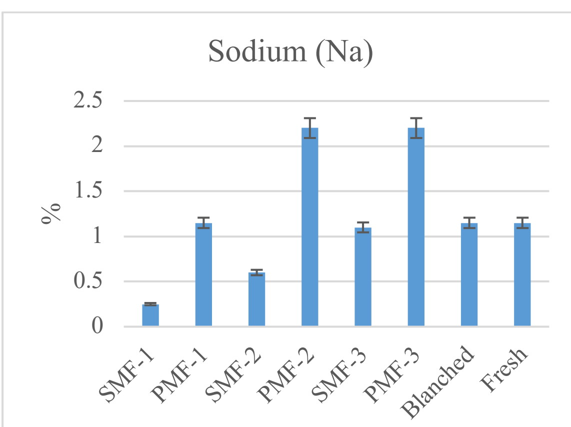

Figure 2 a: Effect of MF pretreatment on Na of SP

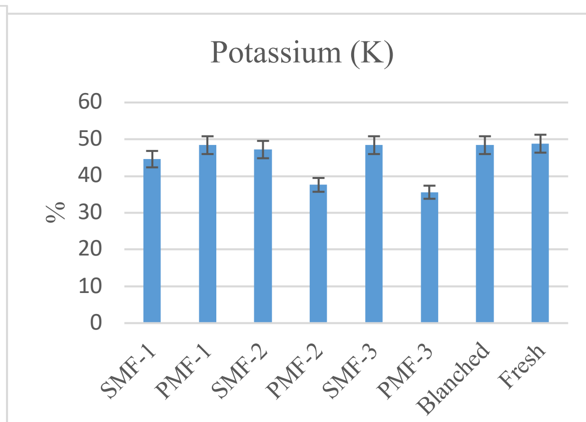

Figure 2 b: Effect of MF pretreatment on K of SP

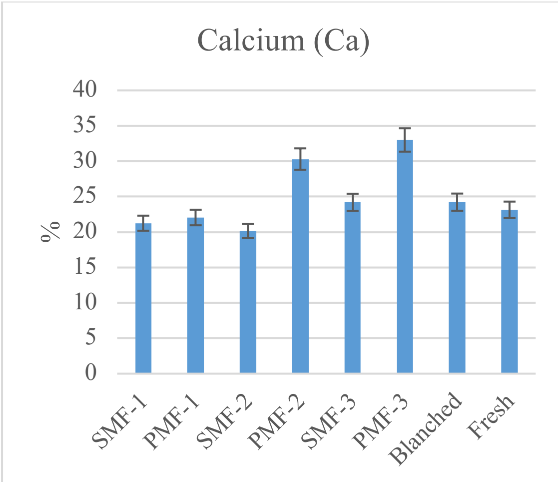

Figure 2 c: Effect of MF pretreatment on Ca of SP

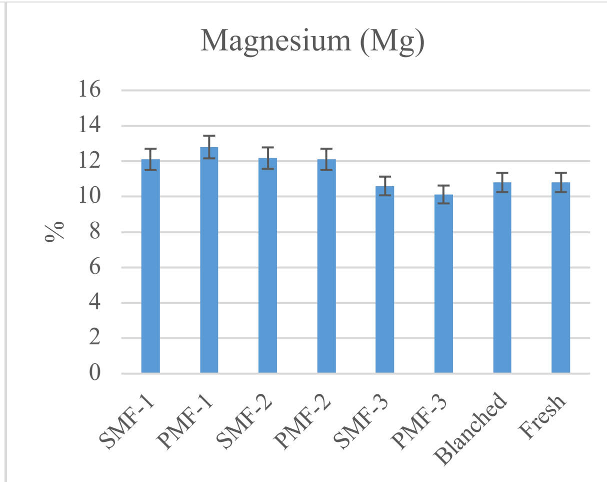

Figure 2 d: Effect of MF pretreatment on Mg of SP

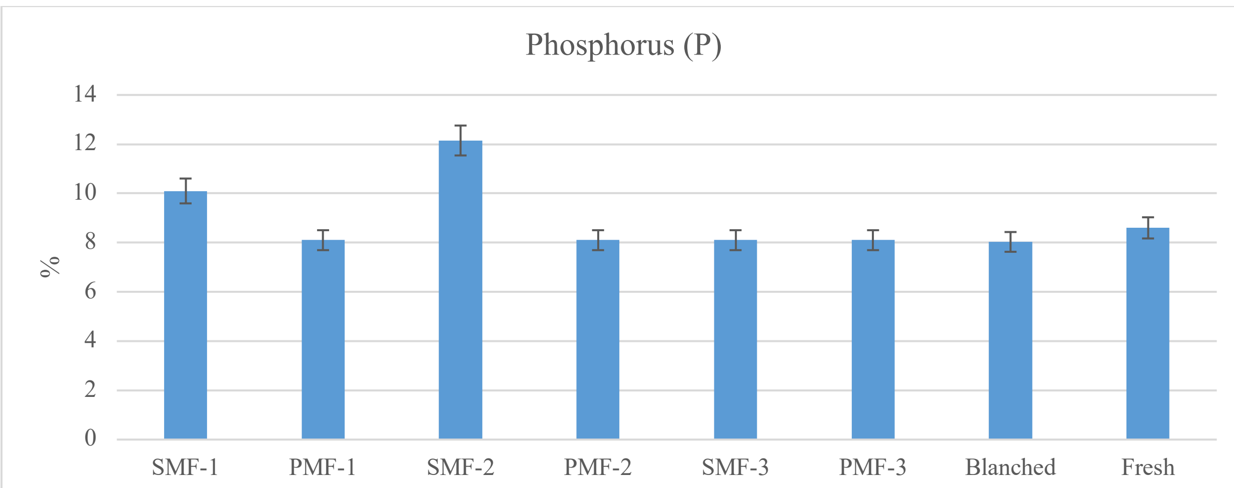

Figure 2 e: Effect of MF pretreatment on P of SP

4. Conclusions

The impact SMF and PMF pretreatments on the microstructures and elemental distribution of sweet pepper in comparison with blanched and fresh samples are not the same. Generally, SMFs exhibited undetached outlooks unlike PMFs that are more of visible segregated microstructures. The elemental analysis established that magnetic field pretreatment at some combination of factors (PMF-2, PMF-3, PMF-1 and SMF-2) led to significant improvement/better retention in values of most elements (Na, Ca, Mg and P) considered than blanched and fresh samples at 5% probability level. Hence, magnetic field pretreatment (which is non-thermal) is more beneficial than blanching (thermal) pretreatment for the processing of vegetables. Further research on the use of higher values of magnetic field strength in combination with other processing factors with the consideration of more micronutrients, macronutrients and phytonutrients is recommended.

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