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Research Article

Effect of electromagnetic field pretreatment on the phytonutrient content of sweet pepper and fluted pumpkin leaf

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Abstract: Electromagnetic field (EMF) pretreatment is a novel non-thermal technique of food pretreatment that ensures better food quality than thermal techniques. This study aimed to study the effect of electromagnetic pretreatment on the phytonutrients of two vegetables: sweet pepper (SP) and fluted pumpkin leaf (FPL). Three types of magnetic fields (static, pulse and alternating) in combination with magnetic field strength (5 - 30 mT) and pretreatment time (5 - 25 min) were used to pretreat SP and FPL. All EMF pretreated, blanched (control) and fresh samples were analysed before and after drying for five phytonutrients, and data were processed and presented with bar charts. Carotenoids of SP before and after drying were 33 mg/1 and 48 mg/1respectively. Highest values of phenols for SP were 0.28 mg/l and 0.15 mg/l before and after drying respectively. FPL had carotenoids (40 mg/l - 45 mg/l), alkaloids (1.1 mg/l), phenol (1.6-2.4 mg/l) while flavonoids content after drying increased (6.7% - 21.70%). Saponins content of FPL remained the same before and after drying. EMF pretreatment relatively led to significant improvement in the phytonutrients of SP and FPL than blanching.

Keywords: Electromagnetism; non-thermal; phytochemicals; processing; vegetables

1. Introduction

Phytonutrients are naturally occurring protective chemicals that are found in foods of plant origin and plant-based diets (Poe, 2017). They are broadly classified into three categories, namely, polyphenols, carotenoids and allyl sulfides, and are highly present in fruits, vegetables, nuts and seeds (Han et al., 2007; Abourashed, 2013; Ahmad, 2019; Ayaz et al., 2019). Phenols concentration depends on the competition for the allocation of photosynthetically fixed carbon to growth or defense (Sakihama et al., 2002; Wuyts et al*.,* 2006); and could also be an essential part of plants protective mechanism against abiotic and biotic stresses (Singh et al., 1999; Mittler, 2002; Wuyts et al*.,* 2006). Phytonutrients are reported to have significant contributions and positive effects on human metabolism and serve as a basis for more than 40 percent of medications (Jillian Levy, 2015). In other words, phytonutrients have therapeutic characteristics as a result of their ability to provide defense mechanism to supplement antibodies in the body systems and also have strong effect in the prevention of heart disease, urinary tract infections, rheumatoid, arthritis, cancer; improving immunity and regulation of blood pressure (Abourashed, 2013; Li et al., 2016; Poe, 2017; Ahmad, 2019).

Sweet pepper (*Capsicum annum*) is a genus of plants from the *Solanaceae* family. It is usually pronounced as "tatase" among the Yoruba and Hausa tribes of Nigeria (Kays, 2011; Oyewo et al., 2018). It contains essential nutrients for healthy living because of its natural antioxidants, especially vitamins C and E which makes it form an important part of the human diet (Slavin and Lloyd, 2012; Wallace et al*.,* 2019). Generally, peppers contain essential nutritional antioxidants that may reduce the risk of degenerative,

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mutagenic and chronic diseases (Ozcan et al., 2014). Fluted Pumpkin Leaf (*Telfaria occidentalis*) is a leafy vegetable and an edible herbaceous plant (Oselebe et al., 2013). It is popularly called "ugu" among the Igbo ethnic group of Nigeria (Odewole et al., 2015). Functional compounds such as β-carotene, anti-oxidants, and phenolic (such as anthocyanin and other flavonoids) are found in fluted pumpkin leaf (Olayiwola et al., 2013). Medicinally, it is known for body stabilization by neutralizing free radicals in the human body (Sikora & Bodziarczyk, 2012) and also offers some recuperative advantages in managing challenges such as diabetes, histaminic, cancer and bacterial activities (Acikgoz, 2011; Oulaï et al., 2016). Obeagu et al. (2014) reported that fluted pumpkin leaf has anti-cholesterolemic and anti-inflammatory characteristics, as well as hematological parameters.

Food pretreatment is the process of maintaining the desired properties of food for as long as possible to ensure the consumption of food with high nutritional values (Rahman & Perera, 2007). Also, pretreatment offers a unique advantage of enhancing further processing of food by ensuring quality retention and extension of storage life. Food pre-treatment/processing methods can be broadly classified into two; these are conventional and non-conventional (emerging or novel technology) methods (Neetoo & Chen, 2014). Conventional means of food pre-treatment is prevalent and varies from one locality to another. It has both thermal and non-thermal types. Examples of conventional method of food pretreatments that are thermal are blanching, parboiling, thermal pasteurization and thermal sterilization; whereas the typical non-thermal examples are mechanical shape and size adjustment operations; and the use of chemical compounds present in some solid, liquid or gaseous materials. The conventional method of food processing (most notably the thermal application) guarantee food safety but can cause loss of temperature-sensitive nutrients, change of structure, change of colour and taste (Lipiec et al., 2004; Neetoo and Chen, 2014). Non-Conventional method of food pretreatment is not as popular as the conventional method because it is still classified as emerging or novel technology (Neetoo & Chen, 2014). Retention of nutrients and sensory properties, and the extension of shelf life without adverse effect on food quality are some of the objectives of novel food pretreatment method; and they are used for all foods for better retention of quality and greater acceptance (Neetoo & Chen, 2014; Režek et al., 2018; Zhao et al., 2019). The method is also sub-divided into thermal and non-thermal types. Some typical examples of the non-conventional pretreatment method that are thermal are ohmic heating, microwave heating and *sous vide*. Whereas, some of its non-thermal types are: High Hydrostatic Pressure (HHP), Pulsed Electric Field (PEF), pulsed light, irradiation, Ultra sonics, Pulsed X-Rays (Neeto & Chen, 2014; Zhao et al*.,* 2019) and the use of the magnetic field (Haile et al., 2008; Hayder et al., 2015).

Magnetism is the concept that leads to the generation of a magnetic field. Magnetic field is a region around a magnet where a magnetic force can be detected (Nelkon & Parker 1995). Magnetic fields can be classified based on three criteria; these are relative strength (low or high intensity), the variation of intensity with space (homogeneous and non-homogeneous), and variation of intensity with time (static or pulsed magnetic fields). Low-intensity magnetic fields include areas in order of tens of Gauss (1Tesla equals 10000 Gauss); whereas, high-intensity field is over thousands of Gauss. Homogeneous magnetic fields have intensities that are constant over space, but the intensity of non-homogeneous magnetic fields varies across space. The intensity of the static magnetic field remains steady over time, whereas the intensity of the pulsed magnetic field changes over time (Barbosa-Canovas et al., 2005). Electromagnetism is the generation of magnetic field due to the flow of current in a conductor. Recently, electromagnetic technology in food processing has gained increased industrial interest and tend to replace the traditional well-established preservation processes (Vincent & Castro, 2007).

The research on the biological effects of magnetic fields started in 1938, but the use of the magnetic field as a non-thermal method of processing food was first proposed in 1985 when a U.S. patent was granted to Hofmann (Barbosa-Canovas et al., 2005). ICNIRP (2009) reported that human being could be safely exposed to 0.4 – 8 Tesla strength of the magnetic field. In explaining the concept of the magnetic field for food pretreatment, it was stated that magnetic field can change the free radicals, the concentration of ions and electrical charges without any degradation in the chemical profile of food products and it will make the membrane to be more permeable, and the free movement of ions would activate the metabolic pathways by enhancing the biochemical and physiological feedback (Jamil et al., 2012). In a related article, Dhawi et al. (2009) said living cells (food inclusive) have ions or free radicals which create internal magnetic field within them; when the food is placed within an external magnetic field produced by either permanent magnet or electromagnet, there will be an interaction between the internal magnetic field of the food and the external magnetic field. This interaction would cause alteration in the arrangement of the ions or free radicals of the food leading to the modification of structures and nutrients present in the food.

Research works exist on the use of the magnetic field for the pretreatment of irrigation water; treatment of wastewater; pretreatment of seeds before planting; treatment of drinking water, and in the health sector for treating ailment and for diagnostic purposes (Stolfa et al., 2007; Jamil et al., 2012; Shams et al., 2013; Ajitkumar, 2014; Ali et al., 2014; Rawabdeh et al., 2014; Yusuf and Ogunlela, 2016). Also, magnetic field pretreatment has been previously used to achieve the following in food processing: modification of microstructures and adjustment of the distribution of some food nutrients (Odewole et al., 2020); reduction in microbial load of foods (Lipiec et al., 2004; Haile et al., 2008; Hayder et al., 2015); softening of meat (Ordonez & Berrio 2011); reduction of respiration rate of fruit as well as wound reduction during cutting (Jia et al., 2015) and creation of positive influence on the lactose content of whey (Kyle, 2015). Apart from the fact that in-depth information on the use of the magnetic field in food processing is still scarce and somewhat sketchy, available literatures did not consider the effect of the magnetic field as a form of pretreatment on the phytonutrients of foods. Therefore, the objective of this study was to study the effect of electromagnetic field pretreatment on the phytonutrients (flavonoids, alkanoids, carotenoids, phenol and saponin) of sweet pepper and fluted pumpkin leaf. This study is important because, many of the heat sensitive phytonutrients of vegetables that are depleted at different stages of processing as a result of their exposure to multiple stages of heat are better retained with the use of magnetic field (a non-thermal pretreatment).

2. Materials and methods

2.1. Materials

The following equipment, tools and materials were used for the experiment: a locally manufactured electromagnetic field pretreatment device at the laboratory of the Department of Food Engineering, University of Ilorin, Ilorin, Nigeria; electronic weighing balance (OHAUS, Model 201, China), laboratory size oven (Model SM9053, England), Microsoft excel worksheet (Version 2016, USA), desiccator, fresh samples of sweet pepper (SP) and fluted pumpkin leaf (FPL).

Table 1: Experimental design and layout

		SP/FPL		SP/FPL		
		SMF/PMF		AMF		
SN		MFS (mT)	PT (min)		MFS (mT)	PT (min)
1	SMF-1/ PMF-1	13.5	15	AMF-1	9.5	5
2	SMF-2/ PMF-2	19.0	20	AMF-2	5.0	25
3	SMF-3/ PMF-3	19.0	15	AMF-3	9.5	25
4	SMF-3/ PMF-3	19.0	15	AMF-4	9.5	15
5	SMF-3/ PMF-3	19.0	15	AMF-5	5.0	15
6	SMF-4/ PMF-4	8.0	25	AMF-4	9.5	15
7	SMF-5/ PMF-5	8.0	5	AMF-6	14.0	5
8	SMF-3/ PMF-3	19.0	15	AMF-4	9.5	15
9	SMF-6/ PMF-6	19.0	10	AMF-4	9.5	15
10	SMF-7/ PMF-7	24.5	15	AMF-7	14.0	15
11	SMF-8/ PMF-8	30.0	25	AMF-8	5.0	5
12	SMF-9/ PMF-9	30.0	5	AMF-4	9.5	15
13	SMF-3/ PMF-3	19.0	15	AMF-9	14.0	25

SMF-Static Magnetic Field; PMF- Pulse Magnetic Field; AMF-Alternating Magnetic Field;
MFS - Magnetic Field Strength; PT- Pretreatment Time.
Sample of interpretation of pretreatment combination codes: SMF-1 is SMF @ 13.5 mT MFS and 15 min PT; PMF-1 is PMF @ 13.5 mT MFS and 15 min PT; AMF-6 is AMF @ 14.0 mT MFS and 5 min PT.

2.2. Methods

2.2.1. Use of the electromagnetic field device

Fresh samples of SP and FPL were procured, sorted, washed and cut into pieces. After these, uniform experimental quantities per run (10 g for FPL and 100 g for SP) were measured with the electronic weighing balance. The measured samples were placed in the electromagnetic field device. Selection of magnetic field types (Static, Pulse or Alternating) with combination of the magnetic field strength (5 - 30 mT) and pretreatment time (5 - 25 min) was done on the electromagnetic field device. Response Surface Methodology type of experimental design in the Design Expert software was used to conduct the experiment and the layout is shown in Table 1. Blanching (100 °C for 3 min) was used as the control pretreatment as well as fresh samples. All electromagnetic field pretreated, blanched and fresh (untreated) samples were dried in the laboratory oven at 50 ˚C and briefly kept in the desiccator to prevent the dried products from absorbing more moisture from the environment before the laboratory analyses.

2.2.2. Laboratory and statistical analyses

AOAC (2005) was used to analyse all the phytonutrients of samples of SP and FPL before and after drying respectively. The Microsoft excel was used to process all the data obtained from laboratory analyses in form of plotting bar charts with the inclusion of statistical significance of 5% error bar. The error statistically showed the effect of electromagnetic field pretreatments combinations on the phytonutrient content of SP and FPL before and after drying respectively.

3. Results and discussions

3.1. Effect of electromagnetic field pretreatment on phytonutrient content of SP

Figs. 1 (a & b) and 2 (a & b) show the effect of electromagnetic field pretreatment on the phytonutrients (flavonoids, alkaloids, carotenoids, phenols and saponin) of SP before and after drying respectively. Specifically, the phytonutrients with highest values of electromagnetic field pretreated SP (with their respective values obtained for blanched in brackets) are: 33 mg/l for carotenoid at SMF-9; 14 mg/l for flavonoids at SMF-6 (about 14 mg/l); 1.1 for alkaloids at PMF-1, AMF-8, PMF-9 and AMF-9 (about 1.1 mg/l), 0.28 mg/l for phenols at SMF-8 (21 mg/l) and 14 mg/l for saponin at PMF-3, PMF-7, AMF-8 and SMF-9 (about 14 mg/l). Generally, before drying, some of the electromagnetic field pretreatment combinations led to a significant increase ($p \leq 0.05$) in the values of the carotenoid, alkaloids, phenols and saponin than the blanched sample at as indicated with the error bar. However, flavonoids of electromagnetic field pretreatment of SP are significantly lower than that of the blanched sample (14 mg/l) except at SMF-8 that has about 14 mg/l. The observation mentioned above implies that electromagnetic field pretreatment (a non-conventional non-thermal technique) at some stages of combined factors performed better than blanching (a conventional cum thermal technique). Meanwhile, after drying, almost all the flavonoids, alkaloids and carotenoids of electromagnetic field pretreated SP are not significantly different from the value obtained for the blanched sample. Blanched sample of SP has flavonoids, alkaloids and carotenoids values of 15 mg/l, 2.2 mg/l and 48 mg/l respectively. However, some of the electromagnetic field pretreatment combinations led to significant increase in phenols (0.04 mg/l) at SMF-9, SMF-7, SMF-1 and AMF-4 and saponins (0.14 mg/l) at AMF-8, AMF-4 and SMF-9 of SP than blanched sample (0.03 mg/l for phenols and 0.14mg/l for saponins). The increase in phenols and flavonoids obtained in some cases in this study are similar to the report in Vishki et al. (2012) for electromagnetic field pretreated *Satureja bachtiarica L.* Aggarwal et al. (2016) also reported a higher content (17.49%) of carotenoids in sulphur dioxide pretreated freeze-dried tomato slices using hot-air drying. In this current study, reasons for carotenoids increased after drying were yet to be verified. In comparison with before drying condition, phenols values reduced after drying. This might be due to the heat-sensitive nature of phenol (Elhamirad & Zamanipoor, 2012; Tiho et al., 2017) and reduction in moisture content. More so, genotypes,

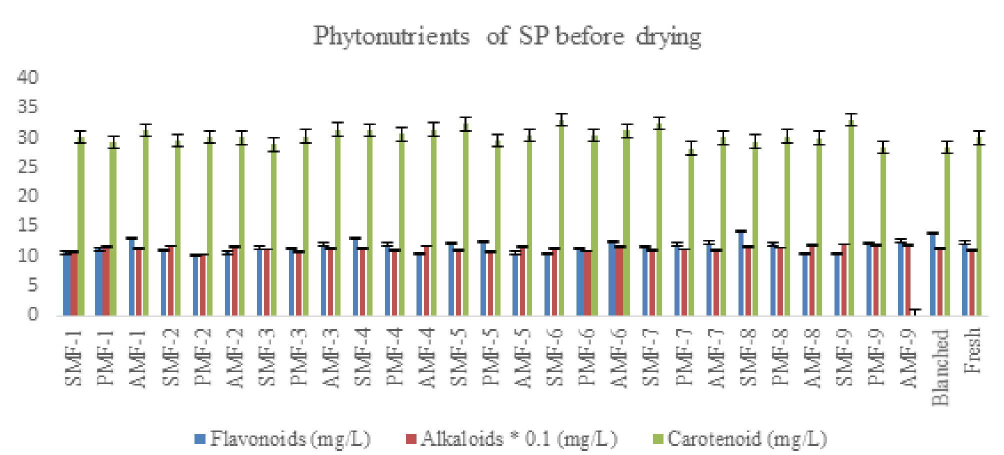

Fig. 1a: Flavonoids, alkaloids, and carotenoids contents of SP before drying

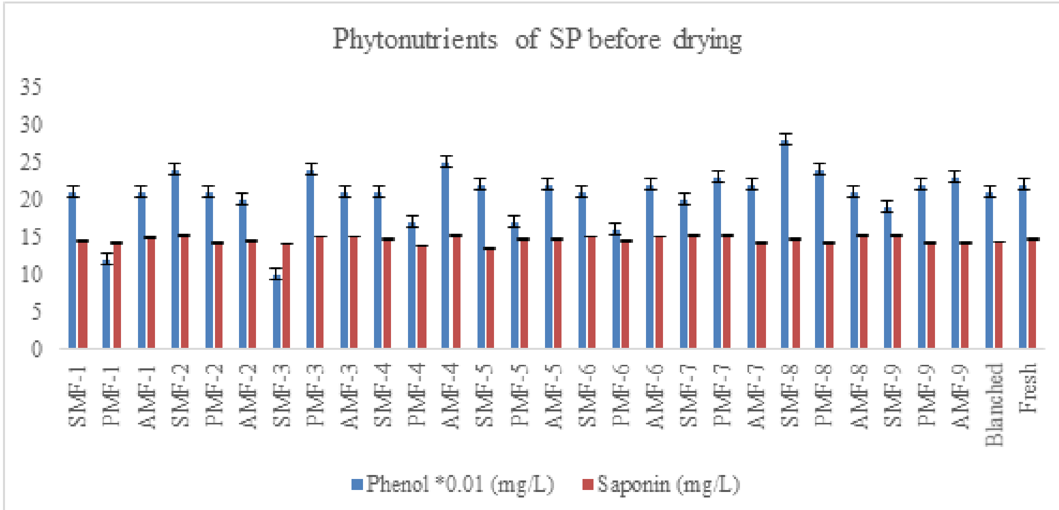

Fig. 1b: Phenol and saponin contents of sweet pepper before drying

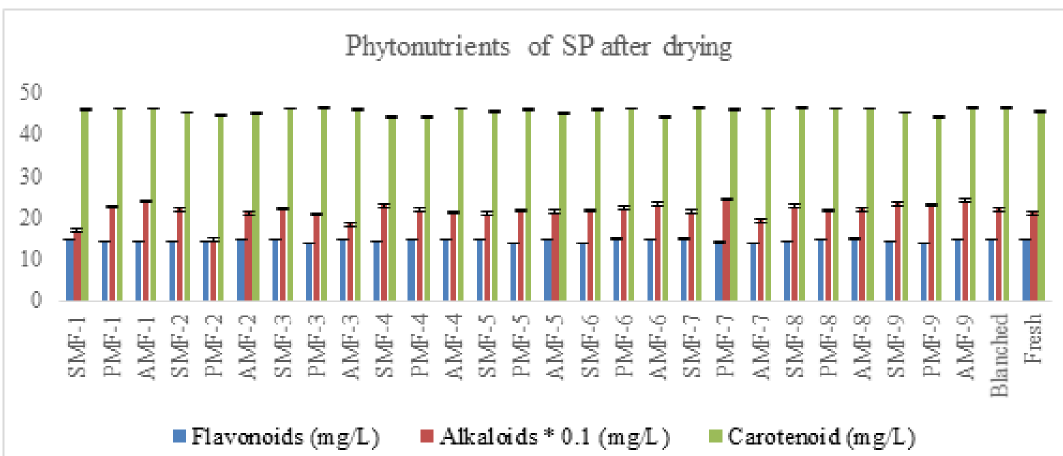

Fig. 2a: Flavonoids, alkaloids, and carotenoids contents of sweet pepper after drying

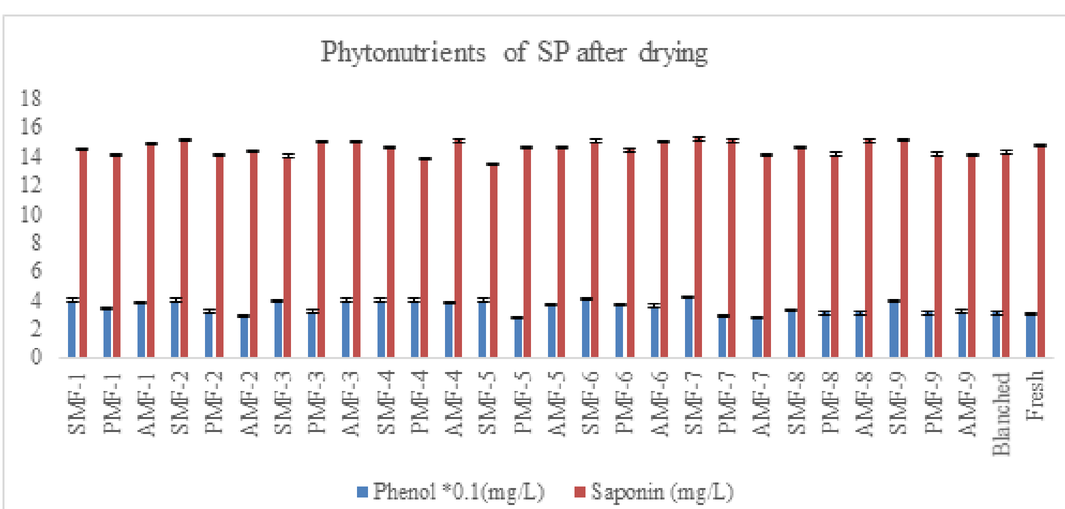

Fig. 2b: Phenol and saponin contents of sweet pepper after drying

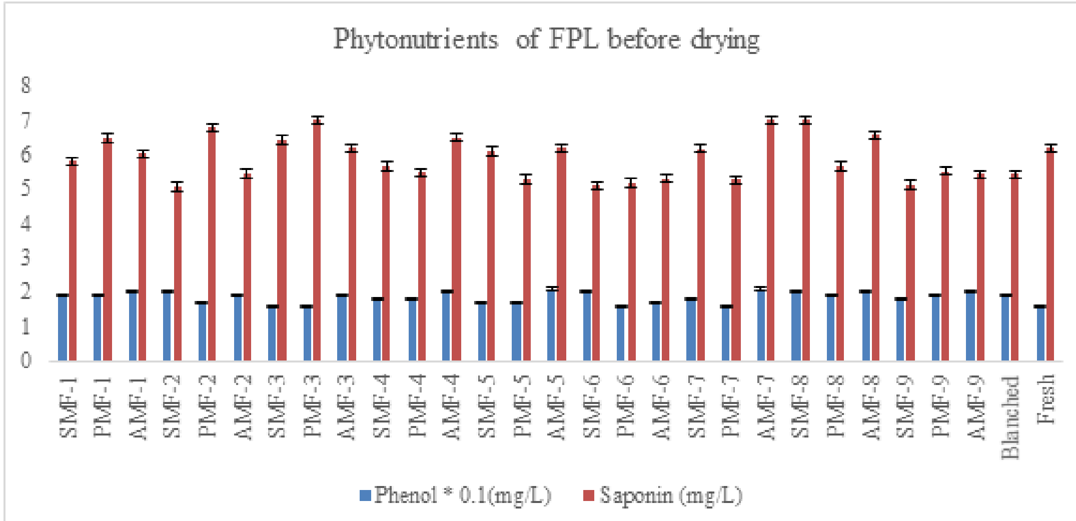

Fig. 3b: Phenols and saponin contents of FPL before drying

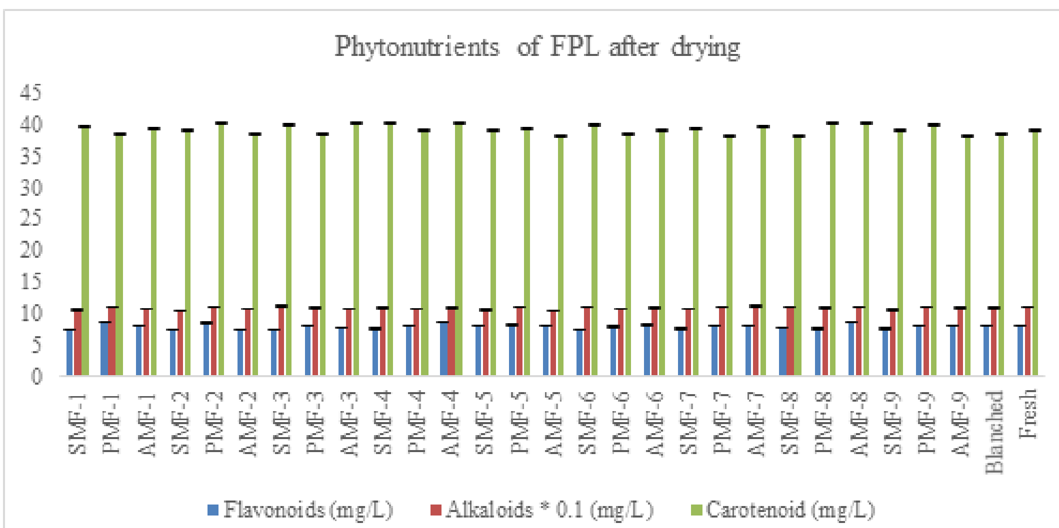

Fig. 4a: Flavonoids, alkaloids, and carotenoids contents of FPL after drying

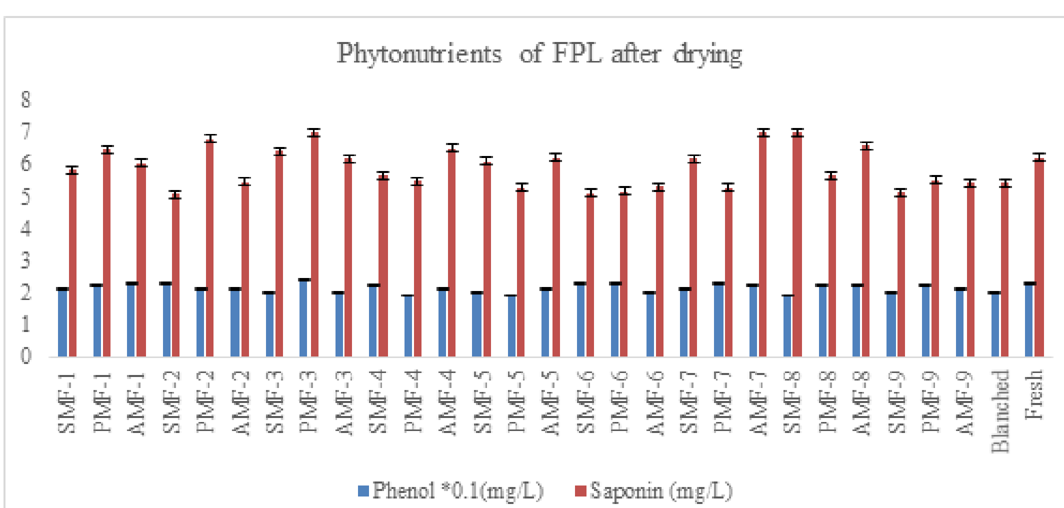

Fig. 4b: Phenol and saponin contents of FPL after drying

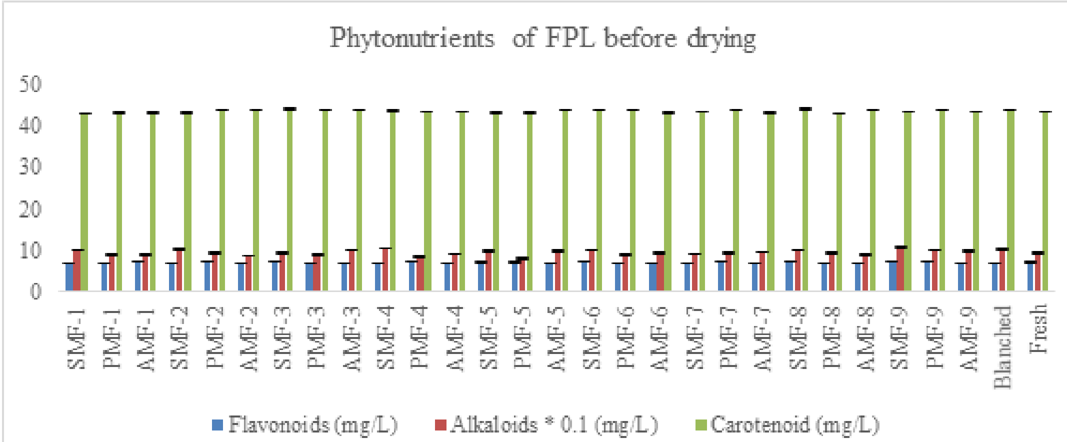

Fig. 3a: Flavonoids, alkaloids, and carotenoids contents of FPL before drying

agro-climatic conditions, post-harvest handling, processing and preparation can influence carotenoids content of sweet pepper (Muhammad Shah et al., 2014; Mohd Hassan et al., 2019) and other phytonutrients.

3.2. Effect of electromagnetic field pretreatment on phytonutrient content of FPL

The effect of electromagnetic pretreatment on the phytonutrient of FPL before and after drying is illustrated in Figs. 3 (a & b) and 4 (a & b). The figures show that electromagnetic field pretreatment had significant effect ($p<0.05$) on the phytonutrients of FPL. The flavonoids, alkaloids and carotenoids of electromagnetic field pretreated FPL before drying are not significantly different from each other in most of the electromagnetic field pretreatment combinations and from that of blanched samples. Flavonoids, alkaloids and carotenoids have 7.5 mg/l, 0.1 mg/l and 44 mg/l respectively. However, dissimilar trends occurred for phenols and saponins, in the sense that, some of the electromagnetic field pretreatment combinations significantly increased the phenols and saponins of FPL before drying. This observation might be attributed to the different characteristics of each SMF, PMF and AMF (Bird, 2010) in combination with different values of magnetic field strength and pretreatment time. At AMF-5, phenols exhibited the highest value of about 0.2 mg/l with blanched sample having slightly below 0.2 mg/l. Similarly, highest value saponins (7 mg/l) was obtained at the following electromagnetic field pretreatment combinations: AMF-7, SMF-8 and PMF-3; and the blanched sample has about 5.5 mg/l.

After drying, the carotenoids level was between the range of 38.14 - 40.31 mg/l in the pretreated samples compared to a value of 38.36 mg/l and 39.1 mg/l in the blanched and fresh samples respectively. Alkaloids of some electromagnetic field pretreated samples FPL are significantly higher than that of the blanched sample. The highest value of alkaloids (2.4 mg/l) is at PMF-7 and that of blanched sample is 2.1 mg/l. Similarly, phenols and saponins of electromagnetic field pretreatment FPL are 0.41 mg/l at SMF-7 and 7 mg/l at AMF-7, SMF-8 and PMF-3 with blanched samples having 0.3 mg/l and 14 mg/l respectively. However, the electromagnetic field did not cause a significant change in the flavonoids of FPL in comparison with blanched samples (15 mg/l). This is quite different from the report of Nguyen and Le (2018) where an increase in total flavonoids, total phenolic content, and saponin content of methanol-extracted dried sliced carrot were observed. The variations observed after pretreating with the magnetic field and drying in this study might be due to the level of phytonutrients in food products which are determined by growth and maturity of the raw food, and the temperature-time effects with processing techniques (Muthukumarappan & Tiwari, 2010). Also, Vu et al. (2017) reported that processing techniques of microwave drying retained a higher total flavonoid than vacuum and hot-air methods of drying *Paramignya. Trimera* root.

4. Conclusion

Electromagnetic field pretreatment caused different effects on the phytonutrients (flavonoids, alkaloids, carotenoids, phenols and saponins) of sweet pepper and fluted pumpkin leaf. In comparison with values of phytonutrients obtained for blanched samples, electromagnetic field pretreatment led to significant improvement or better retention of the selected phytonutrients of the two vegetables in most cases. Therefore, electromagnetic field pretreatment is a possible alternative that can be considered as a replacement for blanching in the vegetable processing value chain.

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