Possibility of Pulsed Electric Field and Essential Oil Pre-treatment, Microwave-air Dehydration to the Quality of the Dehydrated Sesban (Sesbania sesban) Flower

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Abstract

Non-heat ahead-treatment in advance of the main dehydration is essential to preserve the quality and ensure food safety. Pulsed electric field (PEF) utilizes a high-voltage electric field in a very short duration to inhibit microbes and enzymes while maintaining the most sensory and nutritional characteristics. For thermal sensitive components, the dehydration process should be performed at low temperatures. Freeze dehydration, vacuum dehydration required high cost for equipment, energy consumption, low quantity in long dehydration time. Microwave-air dehydration is considered as a promising alternative technical approach. Sesban (Sesbania sesban) flower contains numerous phytochemical components promoting health-benefit. However, it’s highly perishable after harvesting. Consumers enjoy the dried sesban flower as a healthy drink. This study examined the possibility of PEF ahead-treatment in microbial inhibition and enzymatic inactivation; essential oil and Microwave-air dehydration on retention of total phenolic content (TPC), vitamin C, 2,2 diphenyl-1-picrylhydrazyl of free radical scavenging (DPPH), ferric reducing antioxidant power (FRAP) of the dehydrated sesban flower. Research also monitored the microbial stability of the dehydrated sesban flower during 12 months of preservation. Results showed that PEF at pulse strength 1000 kV/cm, pulse duration 90 µs, pulse number 45 was remarkably inactivated polyphenol oxidase and peroxidase in raw material. Rosemary essential oil soaked for sesban flower before dehydration positively preserved the ascorbic acid, phenolic content and antioxidant capacity. These PEF and essential oil ahead-treatments strongly facilitated for the main Microwave-air dehydration. Among different air temperatures from 20°C to 40°C in microwave-air dehydration, the highest Vitamin C, TPC, DPPH and FRAP of the dried flower were recorded at air temperature from 20°C to 30°C with no significant difference. Meanwhile, airspeed 1.2 m/s showed the highest Vitamin C, TPC, DPPH and FRAP of the dried flower with no significant difference with airspeed 1.4 m/s and 1.6 m/s. There was no significant difference in Vitamin C, TPC, DPPH and FRAP of the dried flower by microwave power from 1.15 to 1.45W/g. Therefore, a combination of microwave and air dehydration at air temperature 25°C, airspeed 1.2 m/s, the microwave energy density of 1.45 W/g was recommended to better preserve vitamin C, TPC, DPPH, FRAP. Microbial stability of the dehydrated flower was also observed during 12 months of storage by 3 month-interval sampling. Coliform, yeast and mold criteria in dried product were stable within acceptable limits.

Keywords: Essential oil, PEF, Microwave-air dehydration, sesban flower

INTRODUCTION

High temperature treatment may cause negative impact to the pigment, aroma, and nutritional composition in food products. Non-heat treatment can resolve heat-borne matters. PEF is one of innovative non-heat treatments popularly implemented in food processing and preservation. The core principle of the PEF is the utilization of high electric field pulses in narrow duration generated to sample located between dual electrodes fulfilling the operating space of the PEF cabinet. It operates on mechanism of electroporation on cell membranes by electric pulses in short duration. It’s not only beneficial for microbial inactivation but also ahead-treatment before dehydration. It greatly improved product quality; accelerated dehydration kinetic by reducing the dehydration duration; enhanced rehydration ability.4,5 There were different applications of PEF for liquid, semi-solid and solid foodstuffs. Many literatures mentioned to the utilization of PEF as ahead-treatment before dehydration of apple, red bell pepper, strawberries, sea cucumber, peach.7-10

Ahead-treatment before the main dehydration is vital to obtain high-quality dried products, shorten the dehydration duration, and limit the energy consumption.11 Supplementation of highly antioxidant ingredient to the raw material before dehydration may stabilize its phytochemical constituents of the subjected material.12 Aromatic herbs contain essential oils and polyphenolic antioxidants as natural preservatives.13-16 Essential oil can be utilized as antimicrobial agent against bacteria, yeast, and molds.17 Essential oil is classified into two groups: volatile and nonvolatile fraction.18 Cinnamon (Cinnamomum aromaticum), clove (Syzygium aromaticum) have numerous therapeutic potentials such as antimicrobial, antiviral, anti-inflammatory, cytoprotective.19-21 Cinnamon contains main bioactive constituents
therefore it’s commonly used as a wine preservative.22 Rosemary (Rosmarinus officinalis) oil is applied as a natural antioxidant to enhance food stability.23-24 It is effective to control Fe-induced oxidation.25 Basil (Ocimum-basilicum) oil contains a great amount of phytochemicals contributing to antioxidant and antifungal activities.26-27 Basil oil is approved for use by the EC and FDA.28 Lemongrass (Cymbopogon citratus) is used to retard inflammatory diseases and microbial infectious.29-31 Oregano (Origanum vulgare) oil contains a huge amount of phytochemicals exhibiting therapeutic properties against different ailments.32-37 It could be utilized as an alternative to butylated hydroxytoluene to extend the wholesomeness of meat product.38

Aroma, flavor are important indicators in the quality of dehydrated products.39-40 Moreover, phytochemical constituents are highly sensitive to thermal dehydration. Air dehydration is a conventional method to dehydrate wet porous materials.41 Microwave-air dehydration is highly appreciated as a promising alternative of dehydration technology by providing short dehydration duration and excellent product quality. Microwave and mild air temperature are incorporated to achieve better dehydration effect.42-43 Moisture is easily removed out of raw material by the driving force of vapor pressure gradient.44 Dehydration speed is accelerated by the temperature and moisture content gradients.45 Microwave dehydration is successfully used in different agricultural products.46-49 Microwave-air dehydration induced to shorter dehydration duration with higher dehydration rates and high-quality dehydrated product.50 Microwave-air dehydation was applied for oyster mushroom.51

Sesban (Sesbania sesban) is a shrub widely distributed on paddy field in Dong Thap province, Vietnam during the flooding season. Its flower has been utilized in stew and omelet as fresh and healthy vegetable due to its numerous bioactive ingredients especially anthocyanins, vitamins, phenols, flavonoids possessing antioxidant properties.52 It’s considered as a potential valuable natural antioxidant source with diversified applications in pharmacy and food sector.53 Its flower is highly perishable after harvesting therefore it’s necessary to convert the fresh to the dried form for long-term stability while retaining the most valuable constituents. There are many dehydration methods to reduce its moisture content to safe level. However, hot temperature or prolonged exposure results to degradation of bioactive ingredients inside raw sesban flower. The goal of our investigation verified the influence of PEF ahead-treatment in microbial inhibition and enzymatic inactivation; essential oil and Microwave-air dehydration on retention of TPC, vitamin C, DPPH, FRAP of the dehydrated sesban flower. Research also monitored the microbial stability of the dehydrated sesban flower during preservation.

MATERIAL AND METHOD

Material

Sesban flower was obtained from Binh Phuoc province, Vietnam. Sesban flower was primarily washed under portable water to separate dirty matters, then it’s ahead-treated under PEF to inactivate enzymes and microorganisms. After that, it was subjected to soaking in essential oils ready for Microwave-air dehydration to the final moisture content around 9±0.5oC. The dried sample was kept in plastic bags for 12 months. Chemical reagents such as DPPH; 6-hydroxy2,5,7,8-tetramethylchromane-2-carboxylic acid; 2,4,6-tripyridyl-s-triazine; N, N-diethyl-p-phenylenediamine sulphate; 3-Aminophenol; 2,6-dichlorophenol indophenols; oxalic acid; ethanol; methanol; Folin-Ciocalteu reagent; Na₂CO₃; HCl; FeCl₃; FeSO₄·7H₂O were all analytical grade supplied from De Phat Co. Ltd. Essential oils of cinnamon, clove, rosemary, basil, lemongrass, oregano were purchased from Kobi Co. Ltd. 3M-Petrifilm was received from 3M-Vietnam.

Researching method

Experiment #1

Effect of PEF parameters in ahead-treatment in the microbial and enzymatic inactivation. Different PEF parameters such as pulse strength (500, 750, 1000, 1250, 1500 kV/cm), pulse duration (30, 60, 90, 120, 150 µs), pulse number (15, 30, 45, 60, 75) were verified. The focused variables in this examination were relied on percentage inhibition (%) of polyphenol oxidase, peroxidase activity, Coliform load (log cfu/g).
Experiment #2

Effect of plant essential oil in ahead-treatment to phenolic and antioxidant stability of flower. Flower was soaked with 5% of aqueous suspension (1:1) in 2 minutes of essential oils from cinnamon, clove, rosemary, basil, lemongrass, oregano. The ahead-treated flower was then dehydrated by Microwave-air drier at air temperature 20°C, velocity 0.6 m/s, microwave power density 1.15 W/g. The focused variables in this examination were relied on vitamin C (mg/100g), TPC (mg GAE/100 g), DPPH (mg TE/100 g), FRAP (mg TE/100 g).

Experiment #3

Effect of air temperature, air velocity and microwave power density in Microwave-air dehydration. Different values of air temperature (20, 25, 30, 35, 40°C), air velocity (0.6, 0.8, 1.0, 1.2, 1.4 m/s) and microwave power density (1.15, 1.30, 1.45, 1.60, 1.75 W/g) in Microwave-air dehydration were deeply examined. The focused variables in this examination were relied on vitamin C (mg/100g), TPC (mg GAE/100 g), DPPH (mg TE/100 g), FRAP (mg TE/100 g).

Experiment #4

Microbial stability of the dehydrated sample during storage. In 3 month-interval, the dehydrated samples kept in plastic bags at ambient condition were also taken to monitor coliform (log cfu/g), yeast (log cfu/g) and mold (log cfu/g) load during 12 months of storage.

The dried sesban flowers were grounded by grinder. The grounded powders (50 g) were soaked in methanol (450 mL) for 30 min at ambient condition with periodical agitation. The filtrates were filtered using Whatman No. 2 filter paper with vacuum pump. Each filtrate was concentrated to by vacuum rotary evaporator (RV 3V, IKA, Germany) at 45°C to obtain the end sesban extract.

Physicochemical evaluation

Polyphenol oxidase activity (U) was determined by oxidoreduction potential method via measuring the initial rate of quinone formation, expressed as an acceleration in the absorbance units at 420 nm. An accumulation in absorbance of 0.001/min was considered as one unit of enzyme activity. Mi is initial polyphenol oxidase activity (raw material), and Mi is polyphenol oxidase activity after treatment.

Percentage inhibition (%) of polyphenol oxidase = \( \left( \frac{M_i - M_f}{M_i} \right) \times 100\% \)

Peroxidase activity (U) was determined by spectrophotometric method utilizing N, N-diethyl-p-phenylenediamine sulphate and 3-Aminophenol as a chromogenic reagent. The procedure was established on the enzymatic utilization of \( \text{H}_2\text{O}_2 \) to produce deep-blue substance at wavelength 660 nm. The intensity in absorbance was scaled to the peroxidase activity. \( N_0 \) is initial peroxidase activity (raw material), and Ni is peroxidase activity after treatment.

Percentage inhibition (%) of peroxidase = \( \left( \frac{N_0 - N_f}{N_0} \right) \times 100\% \)

Vitamin C content (mg/100g) was quantified by volumetric method utilizing 2,6-dichlorophenol-indophenol manual titration protocol described by AOAC. Take 1 ml of the testing pure liquid into a 20 mL of flask. Supplement 2 ml of 5% oxalic acid and titrate the reagent (V1, ml). The final point was the occurrence of pink pigment. The quantity of chemical titrated was equal to the quantity of vitamin C. Pattern was weighed (M, g) and filled with 4% oxalic acid to volume (20 ml), separated by centrifugator. Take 1ml of this supernatant with 2 mL of 5% oxalic acid and then titrate one more time the reagent (V2, ml).

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\text{Vitamin C content (mg/100 g)} = \frac{0.5 \times V_2 \times 20 \times 100}{V_1 \times M}
\]

TPC (mg GAE/ 100g) was examined by Folin-Ciocalteau reagent protocol. Extract was dissolved with 90% ethanol (v/v) in a 10 mL tube and centrifuged at 4,000 g within 2.5 min. A 1.4 mL of the extract was combined with 2.0 mL Folin-Ciocalteau reagent 10% (w/v). After 10 min of reaction, 4.0 mL of \( \text{Na}_2\text{CO}_3 \) (5% w/v) was added. Reaction lasted for one hour without light, the absorbance was recorded at 760 nm by spectrophotometer (Shimazu, UV-1800) and compared with a pure linear of gallic acid (0-300 mg/L). \( R^2 \) of the calibration curve was noticed at 0.87.

DPPH (mg TE/100 g) was estimated using UV-VIS spectrophotometric method with mobile phase methanol and water mixed online in the ratio of 80:20 (v/v), injected at a current speed of 1.0 mL/min. Aliquots of the samples 0.5 mL were
supplemented with 3.5 mL of the 0.05 mM DPPH solution in the dark place, and the mixture was thoroughly vibrated and then incubated for 20 min at 37°C. DPPH peaks were quantified at wavelength 517 nm.\(^{58}\) \(R^2\) of the calibration curve was noticed at 0.79.

FRAP (mg TE/100 g) was defined as capacity in reducing of Fe\(^{3+}\) to Fe\(^{2+}\) by an antioxidant utilizing the protocol described by Benzie and Strain.\(^{59}\) FRAP reagent was formulated by diluting acetate buffer (100 mM, pH 3.5), 5 mM 2,4,6-tripyridyl-s-triazine in 25 mM HCl, and 15 mM FeCl\(_3\) at 8:1:1 (v/v/v). All standards and samples were mixed at 500 mg/L in water or methanol. The 100 L reagent, the 20 µL standard (FeSO\(_4\).7H\(_2\)O) or sample and 10 µL water were pipetted to the well and gently mixed. The absorbance were read at 600 nm immediately and 60 min after using a microplate reader. A standard calibration curve of Fe\(^{3+}\) sulphate penta hydrate (FeSO\(_4\).7H\(_2\)O) was plotted at concentrations between 500 and 2000 mM as the reference standard. \(R^2\) of the calibration curve was noticed at 0.83.

Coliform (log cfu/g), yeast (log cfu/g), mold (log cfu/g) were enumerated by 3M-Petrifilm protocols.

### Statistical summary

All tests were arranged in three replications. The values were expressed as average ± standard deviation. Statistical summary was executed by the Statgraphics Centurion version XVI.

### RESULT AND DISCUSSION

**Possibility of PEF as ahead-treatment to the microbial and enzymatic inactivation**

Polyphenol oxidase is commonly available in fruits and vegetables located in various organelles, like chloroplast thylakoids, peroxisomes, and mitochondria.\(^{60}\) Polyphenol oxidase is responsible for enzymatic browning contributing to lower organoleptic property and economical value of foodstuffs.\(^{61-64}\) Polyphenol oxidase caused polymerization of quinones to form brown and black pigments.\(^{65}\) By the way, reaction of polyphenol oxidase led to lower total phenolic content.\(^{66-67}\) In the presence of peroxidase, phenolics were oxidized at the existing of H\(_2\)O\(_2\), inducing to flavour degradation.\(^{68}\) With hydrogen donor, peroxidase converted hydrogen peroxide into H\(_2\)O and O\(_2\).\(^{69}\) The inactivation of peroxidase and polyphenol oxidase was very

| Pulse strength (kv/cm) | 500   | 750   | 1000  | 1250  | 1500  |
|------------------------|-------|-------|-------|-------|-------|
| % inhibition of peroxidase activity | 46.25±0.07\(^b\) | 53.49±0.04\(^ab\) | 59.34±0.05\(^a\) | 60.07±0.03\(^a\) | 60.15±0.02\(^a\) |
| % inhibition of polyphenol oxidase activity | 38.12±0.03\(^b\) | 45.86±0.01\(^ab\) | 52.07±0.04\(^a\) | 52.21±0.02\(^a\) | 52.32±0.03\(^a\) |
| Coliform load (log cfu/g) | 4.36±0.02\(^a\) | 4.01±0.01\(^ab\) | 3.74±0.02\(^b\) | 3.71±0.00\(^b\) | 3.68±0.03\(^b\) |

Values are the average of triplicate; numbers in row accompanied by the alike symbols are not varied significantly (\(\alpha = P=0.05\)).

| Pulse time (µs) | 30    | 60    | 90    | 120   | 150   |
|----------------|-------|-------|-------|-------|-------|
| % inhibition of peroxidase activity | 59.34±0.05\(^b\) | 64.57±0.02\(^ab\) | 72.15±0.01\(^a\) | 72.23±0.02\(^a\) | 72.29±0.03\(^a\) |
| % inhibition of polyphenol oxidase activity | 52.07±0.04\(^b\) | 59.16±0.03\(^ab\) | 65.84±0.02\(^a\) | 66.01±0.00\(^a\) | 66.12±0.01\(^a\) |
| Coliform load (log cfu/g) | 3.74±0.02\(^a\) | 3.09±0.00\(^ab\) | 2.75±0.03\(^b\) | 2.71±0.01\(^b\) | 2.68±0.02\(^b\) |

Values are the average of triplicate; numbers in row accompanied by the alike symbols are not varied significantly (\(\alpha = P=0.05\)).
necessary to retain quality attributes of samples during processing. Thermal treatment was utilized to inactivate the enzyme activity, but it led to negative damage on sensory and proximate compositions.\textsuperscript{70} Non-heat treatment was highly preferred to overcome damage of colour, flavour and heat-sensitive components in food.\textsuperscript{71}

The impact of pulse strength (500, 750, 1000, 1250, 1500 kV/cm) on polyphenol oxidase (PPO), peroxidise (POD) activity and \textit{coliform} load on the flower was illustrated in Table 1. There were trends of increasing % inhibition of peroxidase activity (46.25±0.07 to 60.15±0.02 %) and % inhibition of polyphenol oxidase activity (38.12±0.03 to 52.32±0.03 %) by increasing pulse strength from 500 to 1500 kV/cm. Meanwhile there was a declining trend of \textit{Coliform} load (from 4.36±0.02 to 3.68±0.03 log cfu/g) by increasing pulse strength from 500 to 1500 kV/cm. There was no significant difference of % inhibition of peroxidase activity, % inhibition of polyphenol oxidase activity and \textit{Coliform} load by pulse strength 1000, 1250 and 1500 kv/cm treatment. Therefore, pulse strength 1000 kV/cm was selected for further experiments.

The influence of pulse duration (30, 60, 90, 120, 150 µs) on polyphenol oxidase (PPO), peroxidise (POD) activity and \textit{coliform} load on the flower was presented in Table 2. There were trends of increasing % inhibition of peroxidase activity (59.34±0.05 to 72.29±0.03 %) and % inhibition of polyphenol oxidase activity (52.07±0.04 to 66.12±0.01 %) by increasing pulse time from 30 to 150 µs. Meanwhile there was a declining trend of \textit{Coliform} load (from 3.74±0.02 to 2.68±0.02 log cfu/g) by increasing pulse time from 30 to 150 µs. There was no significant difference of % inhibition of peroxidase activity, % inhibition of polyphenol oxidase activity and \textit{Coliform} load by pulse time 90, 120 and 150 µs treatment. Therefore, pulse time 90 µs was selected for further experiments.

The effect of pulse number (15, 30, 45, 60, 75) on polyphenol oxidase (PPO), peroxidise (POD) activity and \textit{coliform} load on the flower was recorded in Table 3. There were trends of increasing% inhibition of peroxidase activity (72.15±0.01 to 92.73±0.02 %) and % inhibition of polyphenol oxidase activity (65.84±0.02 to 85.07±0.00 %) by increasing pulse number from 15 to 75. Meanwhile there was a declining trend of \textit{Coliform} load (from 2.75±0.03 to 1.95±0.01 log cfu/g) by increasing pulse number from 15 to 75. There was no significant difference of % inhibition of peroxidase activity, % inhibition of polyphenol oxidase activity and \textit{Coliform} load by pulse number 45, 60, and 75. Therefore, pulse number 45 was selected for further experiments.

It’s thoroughly realized that under pulse strength 1000 kV/cm, pulse duration 90 µs, pulse number 45 could effectively inactivated 84.96±0.00 % of polyphenol oxidase, 92.34±0.02 % of peroxidase activity and 2.03±0.01 log cfu/g of \textit{Coliform} load. Increasing electric field density (EFD) and treatment duration resulted to more enzyme inactivation.\textsuperscript{72-73} Bipolar mode was superior to monopolar mode inducing to greater inactivation of polyphenol oxidase, while monopolar pulse was more beneficial to peroxidase inactivation.\textsuperscript{72} Peroxidase and polyphenol oxidase inactivation was strongly correlated to the damage of $\alpha$-spiral of secondary structure.\textsuperscript{74} A 70 % maximum inactivation of polyphenol oxidase activity was noticed after 5 ms applying width pulses at 0.02 ms in bipolar regime at 24.30 kV/cm.\textsuperscript{75} 97 % of polyphenol oxidase and peroxidase in plant-based product was inactivated under PEF processing.\textsuperscript{76} PPO activity in apple extract was completely inhibited at 40 kV/cm, width pulses >

| Pulse number | 15 | 30 | 45 | 60 | 75 |
|--------------|----|----|----|----|----|
| % inhibition of peroxidase activity | 72.15±0.01<sup>b</sup> | 80.37±0.03<sup>ab</sup> | 92.34±0.02<sup>a</sup> | 92.60±0.03<sup>a</sup> | 92.73±0.02<sup>a</sup> |
| % inhibition of polyphenol oxidase activity | 65.84±0.02<sup>b</sup> | 73.52±0.01<sup>ab</sup> | 84.96±0.00<sup>a</sup> | 85.02±0.01<sup>a</sup> | 85.07±0.00<sup>a</sup> |
| \textit{Coliform} load (log cfu/g) | 2.75±0.03<sup>a</sup> | 2.29±0.02<sup>ab</sup> | 2.03±0.01<sup>b</sup> | 1.99±0.02<sup>b</sup> | 1.95±0.01<sup>b</sup> |

Values are the average of triplicate; numbers in row accompanied by the alike symbols are not varied significantly ($\alpha = P=0.05$).
10077. PPO activity in apple was reduced by 3.15% at 24.6 k/cm in 6 ms. 78 71% of PPO activity in apple extract was inactivated by preheating at 50°C and PEF in 100 µs at 40 kV/cm. 79 70% polyphenol oxidase activity in apple extract was inactivated by PEF at 38.5 kV/cm and 300 pulse/s by preheating at 50°C. 80 48% polyphenol oxidase activity in apple juice was destabilized by preheating to 40°C and PEF at 30 kV/cm. 81 90% of peroxidase and polyphenol oxidase in carrot and apple mash was inactivated by PEF at 80°C. 82 PEF as ahead-treatment could minimize the dehydration duration 25% and improved the rehydration property of freeze-dried apple. 9 PEF stabilized the appearance and improved porosity of freeze-dehydrated apple. 7 PEF stabilized the appearance and improved porosity of freeze-dehydrated apple. 7 Rehydration capacity of the dehydrated red bell pepper and strawberries increased by up to 50% under PEF in advance of dehydration. 10 Dehydration duration was shorter and rehydration ratio became higher on sea cucumber ahead-treated by PEF. 8 PEF was demonstrated to inactivate on microorganisms in apple juice. 83-85 PEF at 35 kV/cm and 90 µs sterilized S. cerevisiae 5.30 log and E. coli 5.15 log. 86 Antimicrobial by PEF could be due to cell membrane perforation. This phenomenon induced to increasing of cell membrane rupture and permeability, irreversible holes resulting to the overflow of macromolecules through the pores. 86 Membrane permeability became higher by accelerating the EFD. The elevated membrane instability led to destruction of microbial cells. Spores were more stable to vegetative cells under PEF. 87 The EFD of 10.82 kV/cm and 120 pulses resulted to reduction of total plate counts of 1.18×10^4 cfu/g to < 10 cfu/g of mesophilic aerobic bacteria in date palm. The EFD of 8.84 kV/cm and 90 pulses caused a elimination of total plate counts of 3.27×10^3 cfu/g of yeasts and fungi to < 10 cfu/g. When 10.82 kV/cm of EFD and 60 of pulses number were used, non-detectable levels of yeasts and molds were noticed. 1 PEF (2.9 kV/cm, 100 Hz, 5000 pulses, pulse duration 10 µs) was applied to inactivate S. cerevisiae. 88 Yeast/fungus and mesophilic bacterial activity was thoroughly inhibited in apple extract treated by PEF during 3-month storage. 77

### Table 4. Effect of herbal essential oil ahead-treatment prior to Microwave-air dehydration to phenolic content and antioxidant capacity in flower

| Essential oil | Cinnamon | Clove | Rosemary | Basil | Lemongrass | Oregano |
|---------------|----------|-------|----------|-------|------------|---------|
| Vitamin C (mg/100g) | 25.45±0.12d | 29.66±0.08ad | 51.35±0.11a | 42.14±0.07b | 37.50±0.12c | 34.11±0.09c |
| TPC (mg GAE/100g) | 86.32±1.28d | 91.07±2.35cd | 136.19±1.64d | 115.24±0.95b | 108.42±1.16c | 100.67±1.29c |
| DPPH (mg TE/100g) | 147.31±1.54d | 152.43±1.37d | 196.07±1.29d | 175.20±1.33d | 167.14±1.21c | 159.78±1.09c |
| FRAP (mg TE/100g) | 764.15±2.40d | 807.53±2.19d | 1327.19±1.58d | 968.15±2.04b | 916.42±1.83c | 871.24±1.61c |

Values are the average of triplicate; numbers in row accompanied by the alike symbols are not varied significantly (α = P=0.05).

### Table 5. Impact of air temperature in microwave-air dehydration to phenolic content and antioxidant capacity in dried flower

| Air temperature (°C) | 20 | 25 | 30 | 35 | 40 |
|----------------------|----|----|----|----|----|
| Vitamin C (mg/100g) | 37.32±0.07a | 37.15±0.04a | 32.67±0.03a | 29.60±0.05a | 17.18±0.02a |
| TPC (mg GAE/100g) | 107.16±0.73a | 105.83±0.91a | 96.42±0.69ab | 92.27±0.57b | 73.46±0.45c |
| DPPH (mg TE/100g) | 130.75±0.89a | 128.96±1.01a | 101.30±1.18ab | 94.05±0.98b | 79.12±0.83c |
| FRAP (mg TE/100g) | 1038.51±1.15a | 1029.17±1.03a | 947.25±1.24ab | 906.73±1.08b | 724.08±0.95c |

Values are the average of triplicate; numbers in row accompanied by the alike symbols are not varied significantly (α = P=0.05).
Impact of herbal essential oil ahead-treatment prior to Microwave-air dehydration

There were many changes of raw material after dehydration like shrinkage, porosity, biopolymer structure, and biochemical activity. Purpose of pre-dehydration treatment focused on either quality enhancement of the dried product or accelerated dehydration kinetics. Inorganic compounds (Sulfur dioxide, calcium, sodium, Na₂CO₃), organic compounds, biopolymers, surface active agents were literatured in pre-dehydration treatment. Influence of essential oils from cinnamon, clove, rosemary, basil, lemongrass, oregano in ahead-treatment prior to Microwave-air dehydration was presented in table 4. It’s clearly noted that among different herbal essential oils, rosemary strongly preserved vitamin C (51.35±0.11 mg/100g), total phenolic content (136.19±1.64 mg GAE/100g), DPPH free radical scavenging (196.07±1.29 mg TE/100g), FRAP ferric reducing antioxidant power (1327.19±1.58 mg TE/100g) in the dried samples. In the European Union, rosemary has been approved as a safe natural antioxidant with low toxicity suitable for food preservation. Dried black chokeberry fruit preliminarily soaked in a suspension of cinnamon or cloves maintained the highest phenolic content during freeze-dehydration. Inclusion of 1% rosemary in the active film of biodegradable serum protein could retard L. monocytogenes effectively. Oregano oil supplemented in the diet (200 mg/kg of diet) improved antioxidant capacity and limited oxidative rancidity in turkey. The impact of lemongrass cinnamon, oregano and clove oils on proliferation and FB1 production of F. proliferatum in irradiated maize grain was evaluated. Cinnamon and oregano oils was greatly beneficial in retarding proliferation and FB1 formation by F. proliferatum in corn. Cinnamon, clove and rosemary oils were useful on retarding lipid oxidation. Clove oil revealed the highest inhibition rate against DPPH radical. Basil oil contained major components such as linalool, methyl chavicol, methyl cinnamate, and eugenol. Effect of air temperature, air velocity and microwave power density in Microwave-air dehydration

Ascorbic acid and polyphenol are the most thermo-labile bioactive constituents in herb and plant. The decomposed reactions of these bioactive substances are catalyzed by high...
temperature, ascorbate oxidase, polyphenol oxidase escaped from damaged cell membranes in dehydration. They should be preserved at utmost level in dehydrated products.

Influence of air temperature (20, 25, 30, 35, 40°C) to phenolic content and antioxidant capacity of dried flower during microwave-air dehydration was elaborated in table 5. By accelerating air temperature (20-40°C), there was declining trends of vitamin C (37.32±0.07 down to 17.18±0.02 mg/100 g), TPC (107.16±0.73 down to 73.46±0.45 mg GAE/100 g), DPPH (130.75±0.89 down to 79.12±0.83 mg TE/100 g), and FRAP (1038.51±1.15 down to 724.08±0.95 mg TE/100 g). The descending trend of phenolic substances and antioxidant capacities in sesban flower during dehydration by increasing air temperature could be explained by thermal-sensitive degradation. There was no significant difference of vitamin C, TPC, DPPH, FRAP by air temperature 20°C, 25°C and 30°C. We decided to choose air temperature 25°C to preserve the most phenolic substances and antioxidant capacities in sesban flower.

Impact of air velocity (0.6, 0.8, 1.0, 1.2, 1.4 m/s) to phenolic content and antioxidant capacity of dried flower during microwave-air dehydration was shown in table 6. By accelerating air speed (0.6-1.6 m/s), there was ascending trends of vitamin C (19.43±0.03 up to 37.15±0.04 mg/100 g), TPC (75.06±0.49 up to 105.83±0.91 mg GAE/100 g), DPPH (81.23±0.39 up to 128.96±1.01 mg TE/100 g), and FRAP (809.72±0.86 up to 1029.17±1.03 mg TE/100 g). The ascending trend of phenolic substances and antioxidant capacities in sesban flower during dehydration by increasing air speed could be explained by quick moisture evaporation rate under high air speed which minimized oxidation. There was no significant difference of vitamin C, TPC, DPPH, FRAP by air speed 1.2, 1.4 and 1.6 m/s. We decided to choose air speed 1.2 m/s to preserve the most phenolic substances and antioxidant capacities in sesban flower.

Effectiveness of microwave power density (1.15, 1.30, 1.45, 1.60, 1.75 W/g) to phenolic content and antioxidant capacity of dried flower during microwave-air dehydration was recorded in table 7. By accelerating microwave power density (1.15-1.75 W/g), there was declining trends of vitamin C (34.25±0.02 down to 14.75±0.01 mg/100 g), TPC (97.60±0.57 down to 70.61±0.58 mg GAE/100 g), DPPH (113.27±0.84 down to 81.53±0.60 mg TE/100 g), and FRAP (997.35±0.63 down to 806.17±0.37 mg TE/100 g). The decreasing trend of phenolic substances and antioxidant capacities in sesban flower during dehydration by increasing microwave power density could be explained by degradation of thermal-sensitive components under high energy of microwave. There was no significant difference of vitamin C, TPC, DPPH, FRAP by microwave power density 1.15, 1.30 and 1.45 W/g. We decided to choose microwave power density 1.45 W/g to preserve the most phenolic substances and antioxidant capacities in sesban flower.

It’s easily noticed that air temperature 25°C, air velocity 1.2 m/s, microwave power density 1.45 W/g resulted to the highest retention of vitamin C (31.05±0.03 mg/100g), total phenolic content (91.23±0.48 mg GAE/100g), DPPH free radical scavenging (106.50±0.42 mg TE/100g), FRAP ferric reducing antioxidant power (961.15±0.81 mg TE/100g) in the dried samples. At low temperature, air velocity and microwave power, the extended exposure of materials in dehydrating condition induced the degradation of bioactive constituents like ascorbic acid, phenolic limiting the health-promoting advantage and antioxidant activity. With the support of microwave, moisture in core of sample migrated.

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Table 8. Microbial load in the dried sample during storage

| Storage (months) | 0       | 3       | 6       | 9       | 12      |
|------------------|---------|---------|---------|---------|---------|
| Coliform (log cfu/g) | 0.15±0.01b | 0.17±0.02b | 0.24±0.03ab | 0.31±0.00ab | 0.38±0.01a |
| Yeast (log cfu/g)   | Not detected | Not detected | Not detected | Not detected | Not detected |
| Mold (log cfu/g)    | Not detected | Not detected | Not detected | Not detected | Not detected |

Values are the average of triplicate; numbers in row accompanied by the alike symbols are not varied significantly (α = P=0.05).
to the surface and escaped greatly to environment even at low temperature of air dehydration. High dehydration rate could prevent overheating and quality decomposition. Microwave could maintain phenolics by inactivating the polyphenol oxidase, lipoxygenase and peroxidase enzymes escaped from the damaged tissue. Different literatures mentioned to the protective advantages of phenolic substances in oat flour tarhana, sour cherry, jujube fruit dehydration with the presence of microwave. Dehydration temperature and microwave power significantly affected to total phenolic content in the dehydrated pomelo. Microwave-air dehydration at 200 W - 60°C on pear slice resulted to higher protection of phytochemical constituents. Basil, lovage, mint, oregano, parsley and rocket leaves were dried by Microwave-air dryer at 40°C, air velocity 0.8 m/s, and power 300 W having high retention of chlorophyll. Air temperature and velocity were important parameters in Microwave-air dehydration to remove moisture leading to homogeneous and faster dehydration. Microwave energy 100 W, temperature 60°C, air speed 0.86 m/s resulted to high ascorbic acid, total phenolic retention in thermal-sensitive food matrix.

Storage of the dehydrated sample

Microbial stability in the dried sample was observed during 12 months of storage (Table 8). Yeast and mold were not detected in the dried sample. Meanwhile, coliform slightly increased during preservation but within acceptable limit. According to the FAO, the lowest water activity for bacteria, yeast, mold was 0.91, 0.88, 0.80 respectively. In the present study, the moisture content in the dried sesban flower was 9±0.5%. This was a very low limit and not suitable for coliform, yeast and mold to growth and proliferation.

CONCLUSION

Ahead-treatment prior to dehydration had two goals: decrease the dehydration duration and enhance properties of the dried product. PEF was an essential ahead-treatment for flower before the official dehydration step to inactivate enzyme, disinfect microbial load at low temperature. It provided short treatment duration, minimal heating damage, and environmental friendly impact. Essential oil of rosemary primarily treated prior to dehydration was useful to protect ascorbic acid, phenolic content and antioxidant capacity of sesban flower. The present research proved that microwave-air dehydration had beneficial advantages to preserve vitamin C, TPC, DPPH, FRAP in the dehydrated flower. The dried flower had microbial load within acceptable limits during 12 months of storage. PEF would be a near-future alternative to conventional thermal processing like blanching. PEF could be successfully utilized in ahead-treatment step before the microwave-air dehydration to protect thermal-sensitive phytochemical constituents. Microwave-air dehydration retained maximal thermo-labile bioactive constituents by avoiding hot temperature or long exposure in mono treatment. Dried sesban flower would be used as a functional food drink contributing to human health.

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DATA AVAILABILITY

All datasets generated or analyzed during this study are included in the manuscript.

ETHICS STATEMENT

Not applicable.

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