The influence of minimal processing on the nutritional and microbiological quality of leafy vegetables

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Abstract The market for dehydrated vegetables it is important for most countries worldwide. Many conventional thermal methods, including airflow, vacuum, and freeze-drying, result in the falling rate period of drying. Minimal processing of vegetables includes methods for preserving of products while minimizing changes of freshness characteristics. A digital microwave oven (Samsung M9G45) and IR digital moisture balance model AD-4714 at 185 W were used for drying of parsley, pig weed and garden sorrel at 2, 4 and 6 minutes. The vitamin C content in the fresh and dried samples was determined by 2.6-dichlorophenol-indophenol method. Microbiological investigations were carried out by plate counting method. In infrared drying, for the garden sorrel leaves, the moisture content (in db) was highest with 71.63% after 2 minutes and with 54.81% after 6 minutes comparative with microwave drying. Ascorbic acid values gave the lowest results (7.98 $mg \cdot 100^{-1} \cdot g^{-1}$ db, respectively 3.01 $mg \cdot 100^{-1} \cdot g^{-1}$ db for infrared and microwave dried garden sorrel) after 6 minutes. For MW, the contamination reduction (4 log) was obtained in the case of pig weed after 6 minutes of drying. The results showed that in a short period of time the leaf's can be dried in rapidly conditions.

Keywords: leafy vegetables, microwave processing, infrared drying, nutritional and microbiological quality.

1. Introduction

In last decade, in Romania the growth in popularity of convenient foods has stimulated increasing demand for high-quality dehydrated vegetables and fruits that can be used as a garnish, for seasoning and in the instant food sector as ingredients for fabrication of special products (Vegeta, Knorr products). Dehydration offers possibilities of preserving foods in a stable and safe condition as it reduces water activity and extends shelf-life much longer than that of fresh fruits and vegetables. Many conventional thermal methods, including airflow drying, vacuum drying, and freeze-drying, result in low drying rates in the falling rate period of drying [1, 2, 3]. The long drying times at relatively high temperatures during the falling rate periods often lead to undesirable thermal degradation of the finished products [4].

Microwave drying offers opportunities to shorten the drying time and improves the final quality of the dried products. Infrared radiation is electromagnetic radiation with a wavelength between 0.7 and 300 μm, so wavelength is longer (and the frequency lower) than that of visible light, but the wavelength is shorter (and the frequency higher) than that of terahertz radiation microwaves. Infrared radiation can be used as a deliberate heating source and is also gaining popularity as a drying safe method giving a better quality product [5]. As an alternative to hot air, the high operating temperatures generated by infrared heat may be used to remove moisture from the surface of a product while keeping it brown or crispy. This is particularly useful in such applications as drying or baking in the food industry. Infrared can be used in cooking and heating foodstuffs. Food after being infrared dried may be preserved, pulverized or put to other appropriate processes to make the desired processed food or other foods.

Parsley (*Petroselinum hortense*) is a culinary, medicinal and aromatic plant. The fresh or dried leaves, roots and seeds of this plant are used in the food, cosmetic and pharmaceutical industries to produce spice, essential oils and drugs [6]. It is a very rich source of vitamins C and E, β-carotene, thiamin, riboflavin and organic minerals.

ISSN-1223-7221

Garden sorrel *(Rumex patientia L)* and pig weed *(Atriplex hortensis var.* suber) are a cool season annual popular vegetables. These plants have green or red-lilac leaves, are low in calories and a good source of vitamin C, and therefore are used as a salad or herbs in different gastronomic preparations.

Pig weed, garden sorrel and parsley are highly seasonal in nature. In order to make them available to consumers all year round at low prices, they are subjected to postharvest technological treatments such as drying or freezing.

Drying is the process of removing the moisture in the product up to certain threshold value by evaporation. In this way, the product can be stored for a long period, since the activities of the microorganisms, enzymes or ferments in the material are suppressed via drying [7]. Different drying methods are used in the drying of fruits and vegetables. Hot-air drying is the most common method in the drying of foodstuffs that leads to serious damages such as: worsening of the taste, colour and nutritional content of the product, decline in the density and water absorbance capacity and shifting of the solutes from the internal part of the drying material to the surface, due to the long drying period and high temperature [8, 9, 10, 11, 12, 13].

Microwave drying is one of the emerging food-processing method in the drying of fruits and vegetables and has become widespread because it minimizes the decline in quality and provides rapid and, effective heat distribution in the material as well [14]. Furthermore, high quality product is obtained via microwave drying in addition to the decline in drying period and energy conservation during drying [15].

The basic physical phenomenon that is responsible for the heating of food materials at microwave frequencies is dipole rotation [16]. The dipole rotation mechanism relies on the fact that water molecules are subject to a microwave field that rapidly change direction, the dipoles try to align with the direction of electrical field [17, 18].

Microwave energy is capable of polarizing substances. The electrons in the polarized substance were in motion due to the conversion of electromagnetic energy embedded in the substance into kinetic energy. Electrons bump into each other during this electron movement and their energy is converted to heat energy as a result of friction. Thus, the moisture is removed from the product in the microwave oven [19].

The electrical field provides energy for water molecules to rotate into alignment. The energy is converted into kinetic energy of water molecules and then into heat, when the water molecules realign in the changing electrical field and interact with the surrounding molecules (friction) [20].

The aim of this study was:

- to evaluate the efficacy of microwave and infrared drying techniques for different drying period,
- to determine the changes in the ascorbic acid values of the products after drying,
- to evaluate the evolution of total microorganisms during drying.

2. Experimental

2.1. Materials

Samples of fresh parsley, pig weed and garden sorrel leafs were collected from farms in the Galati region of Romania and used in the drying experiments. They were stored at a temperature of 4 ± 0.5°C until the drying process. Before each drying experiment, the leafs were detached from the stems according to the procedure developed by Soysal (2004) [6]. Due to a high level of moisture, the moisture content of analyzed vegetables was measured individually. Three different samples, from the vegetables leaves, each being 5 g were dried until constant weight at 105 ± 2°C for 24 hours. The initial moisture content of the parsley was 1.46 ± 0.5 dry basis, for the garden sorrel and pig weed was 0.834±0.12 dry basis, respectively 1.31±0.5 dry basis. All the initial moistures content were calculated at g of product.

2.2. Drying equipment and technique

Microwave drying equipment and method

Drying treatment was performed in a domestic digital microwave oven (Samsung M9G45) with a maximum output power 900 W at 2450 MHz. The dimensions for the microwave cavity were 330 mm by 234 mm by 340 mm. Drying was performed on a rotating glass plate with 315 mm diameter at the base of the oven. The drying time at 2, 4 and 6 minutes was manually adjusted using a digital clock.

The leaf's selected from the uniform and healthy plants were dried on the special paper disc with 95 mm diameter. Approximately 3 g in weight of each sample was uniformly spread on the paper disc than was placed in the microwave cavity center on the glass plate. After each drying time, the moisture loss was determined by weighting the paper disc using analytic balance with 0,001 g accuracy (Partner AS 110/C/2). Three different drying trials were conducted at microwave generation power adjusted at 185 W (in correlation with the technical specifications of the infrared heat source) and the values obtained from these trials were averaged and the drying parameters were determined.

IR drying equipment and method

Infrared drying was performed with a IR digital moisture balance model AD-4714, which the following characteristics: precision ±0.2% and power of heat source 185 W. Around 3 g of fresh leaf's were uniform placed on the special aluminum pan with 95 mm diameter. The drying temperature continuous setting up to 105^{o}C using a control knob at different drying times was digital displayed. After drying time the moisture content was displayed with minimum precision 0.1%.

2.3. Ascorbic acid determination

Ascorbic acid is an important nutrient in vegetable. It is a hydro-soluble vitamin and more sensitive to heat, oxygen, light and considered to be highly sensitive to losses during processing [21, 22].

The vitamin C content in the fresh and dried samples was determined by 2.6-dichlorophenol-indophenol visual titration method [23, 24, 25]. The reagents used were 2% HCl solution, ascorbic acid standard containing 0.1 mg L-ascorbic acid in 10 ml of 2% HCl solution and 2.6-dichlorophenol-indophenol solution for titration in 100 ml of distilled water.

2.4. Microbiological analysis

All analyzed leaf materials contain a high level of moisture and microorganisms. The climate conditions, the unpretentious production conditions and often inadequate instructions for the farmers may cause considerable hygienic and quality problems [26]. Microbiological investigations of fresh and dried samples were carried out immediately after processing by indirect method of evaluation of the number of microorganisms [27]. Each sample was analyzed for yeasts, moulds and mesophil aerobic bacteria.

Moulds and yeasts, expressed as colony forming units (cfu) per gram dry matter, were quantified according to ISO 21527-2 (Horizontal method for the enumeration of yeast and moulds. Colony count technique. Part 2. Products with a water activity more than or equal to 0.95). Colonies were enumerated after incubation at 25°C for 5 days on Rose Bengal Cloramphenicol Agar (Scharlau Chemie, Spain).

Total numbers of mesophilic aerobic bacteria, expressed as colony forming units per gram dry basis (cfu/g db), were determined according to ISO 4833:2003 (Horizontal method for the enumeration of microorganisms. Colony count technique). Total numbers of mesophilic aerobic bacteria were enumerated after incubation at 30°C for 3 days on Plate Count Agar (Merck KGaA, Germany) as culture medium.

3. Results and discussion

3.1. Drying process

The microwave oven and the infrared lamp were manually adjusted to the same value of the output power, respectively 185 W. The moisture content for the leaves it is presented in **Table 1.**

In the initial phase of microwave drying, the high moisture content of the material determined a higher absorption of the microwave power.

If the drying processes continue, the loss of moisture in the product caused a decrease in the absorption of microwave power. Since the initial moisture contents of the leafy vegetables used in drying experiments were relatively constant, the difference in drying time can be considered.

In this order for parsley leafs we observed minimal moisture content after 6 minutes was 74.22±0.15 % water basis (wb) (or 1.10±0.2 db) at microwave drying respectively, 44.53% wb (or 1.70±0.4db) by infrared drying. Comparative with 2 minutes of microwave drying, for pig weed samples, was observed a decreasing of moisture content after

4 minutes with 41.74%, respectively with 51.31% after 6 minutes. In the same time, the same correlation was observed for infrared drying, so was observed a decreasing with 31.05 % after 4 minutes and 54.52 % after 6 minutes.

Table 1. Variation of the moisture content for different drying techniques

Samples / Moisture content, db	Drying time, minutes					
	2		4		6	
	MW	IR	MW	IR	MW	IR
Parsley	1.37±0.3	2.74±0.5	1.24±0.2	2.16±0.5	1.10±0.2	1.70±0.4
Pig weed	1.15±0.1	2.77±0.1	0.67±0.5	1.91±0.2	0.56±0.1	1.26±0.3
Garden sorrel	0.80±0.4	2.82±0.3	0.69±0.4	1.93±0.1	0.61±0.4	1.35±0.2

db – dry basis; MW – microwave drying; IR – infrared drying

By analyses of microwave and infrared drying techniques, for all vegetables at different drying time, the difference of moisture content can be observed. In this order, for the garden sorrel leaves, all the moisture content (in db) was highest in infrared drying, respectively with 71.63% after 2 minutes of drying and with 54.81% after 6 minutes of drying.

3.2. Evaluation of the ascorbic acid content

Quality attribute of the vegetables leaves dried by microwave and infrared techniques was evaluated in respect of vitamin C.

The evolution of the vitamin C content in fresh, microwave and infrared dried vegetable leaves it is presented in **Fig. 1**, respectively **Fig. 2**.

Due to the characteristic of vitamin C (hydro-soluble and more sensitive to heat), from the figure 1 and figure 2, reduction in ascorbic acid levels for the dried samples was recorded depending on time. Ascorbic acid values gave the lowest results (7.98 mg·100^{-1}·g^{-1} db, respectively 3.01 mg·100^{-1}·g^{-1} db for infrared dried and microwave garden sorrel) after 6 minutes drying period. The minimal losses of vitamin C were recorded for the parsley. So, compared with the fresh leaf's (27.35 mg·100^{-1}·g^{-1} db) after 6 minutes of drying, the vitamin C content was 11.15 mg·100^{-1}·g^{-1} db for the infrared drying method, respectively 17.33 mg·100^{-1}·g^{-1} db for microwave drying process.

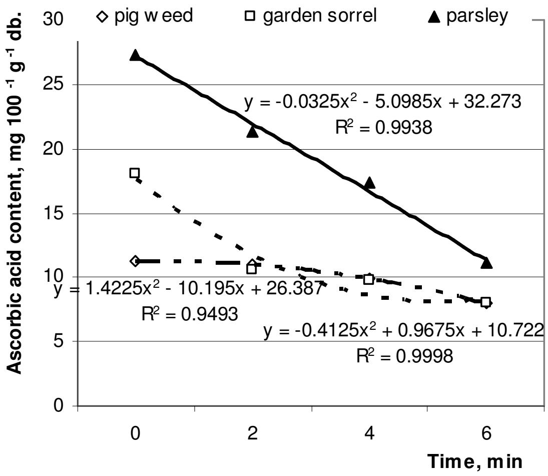

Fig. 1. Effect of infrared drying on acid ascorbic content in different leaf's (185 W, 105°C).

The results are in according with Ozkan et al., 2007 [19] and with Zhang, and Hamauzu, 2004 [28] studies, authors who reported a significant loss of the ascorbic acid with prolonging the treatment period.

The estimations of statistical parameters include also coefficient of determination R^2.

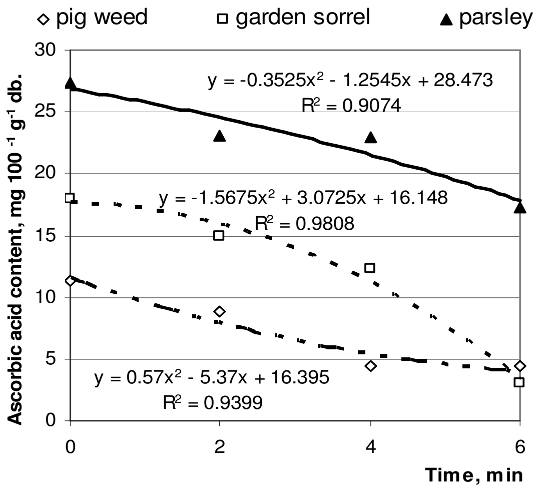

Fig. 2. Evolution of vitamin C after microwave drying (microwave output power 185W)

3.3. Microbiological analysis

Three types of fresh leaf were treated with infrared radiations: pig weed, parsley and garden sorrel. The number of microorganisms was detected before the thermal treatment (initial time) and after 2 minutes, 4 minutes and 6 minutes of infrared treatment.

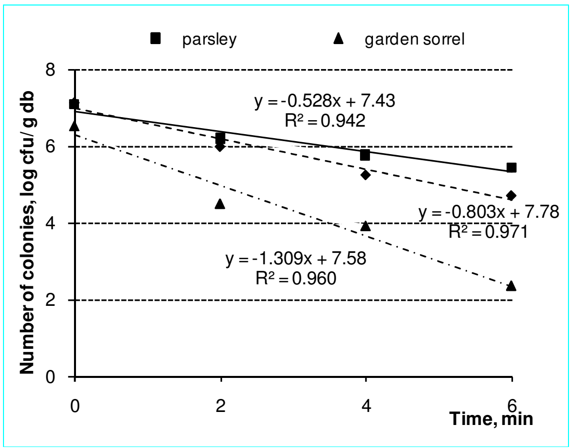

Fig. 3. Evolution of total number of microorganisms per gram dry matter of treated sample during infrared treatment

The results presented in **Fig. 3** indicate that before the treatment (initial time) garden sorrel has the lowest number of microorganisms (3.27x10^6 cfu·g^{-1}d.b). After 6 minutes of infrared treatment on garden sorrel the number of microorganisms decreases with 64.06%.

The same treatment applied for parsley gave a 22.95% reduction and 34.04% for pig weed. The biggest reduction of microbial loading (64.06%) was observed after six minutes of infrared treatment for garden sorrel.

The initial microbial loading was for parsley 8.07 x 10^6 cfu·g^{-1}db, for pig weed 1.30 x 10^7cfu·g^{-1}db and for garden sorrel 3.27 x 10^6 cfu·g^{-1}db. The maximum efficiency after six minutes of microwave drying was observed for the pig weed sample, with a reduction of 61.24%. The microwave treatment induced a reduction of 49.01% for garden sorrel and 51.18% for parsley (**Fig. 4**). Results showed that in a short period of time the leaf's can be dried in rapidly conditions.

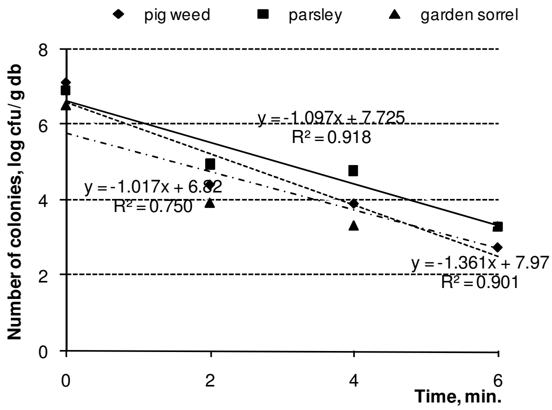

Fig. 4. Evolution of total number of microorganisms per gram dry matter of treated sample during microwave treatment

Microwave drying (MD) technology was appreciated because the moisture content (in water basis) was much higher for all samples at different drying time. Acid ascorbic loss during drying process at the same value of heat source, respectively 185 W, was observed for infrared drying (IR) technology. By performing MW during 2 minutes, the acid ascorbic for parsley was 23.10 mg·100^{-1}·g^{-1}, comparative with 21.32 mg·100^{-1}·g^{-1} of vitamin C obtained by IR. Also for the garden sorrel was observed the same correlation after 2 minutes (14.98 mg·100^{-1}·g^{-1} in MW and 10.53 mg·100^{-1}·g^{-1} in IR), respectively 4 minutes (12.3 mg·100^{-1}·g^{-1} in MW and 9.76 mg·100^{-1}·g^{-1} in IR). For pig weed leafs, the ascorbic acid loss during drying was registered after 2 minutes. The efficiency of the infrared thermal treatment was observed for the garden sorrel and pig weed, which means that 3 log decreasing of initial contamination, was obtained after 6 minutes of IR. For parsley, contamination was significantly reduced (3 log) after 6 minutes of MW process. Anyway, after 6 minutes, the efficiency of the MW process was observed for the pig weed leaf's which means that 4 log decreasing of initial contamination.

Between infrared radiation and microwave treatment the best efficiency for microbial load reduction was obtained in the case of thermal microwave treatment for all three tested leafs. According with our results, we concluded that the microwave drying technology is indicated for drying leafs that can be used as ingredients for instant foods.

The experiments will be continued in order to test other microwave power levels and to evaluate the energy consumption during drying. Also, it is intended to study leafs microstructure changes after the MW and IR treatment.

5. References

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