FOAM-MAT CONVECTIVE AND MICROWAVE DRIED AVOCADO POWDER: PHYSICAL, FUNCTIONAL, AND POWDER PROPERTIES

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***Abstract*—This study aimed to produce hot air (60-80°C and 20% ventilation rate) and microwave (120-700W) assisted foam mat dried avocado powders and to determine the effect of different drying temperatures and microwave powers on physical, functional, and powder properties of avocado powders. Significantly lower drying times were observed for the microwave-assisted foam mat dried avocado powder (MW, p<0.05). Microwave-assisted foam mat dried avocado powders have superior properties in moisture content and flow properties (p<0.05), whereas comparatively better results were obtained for hot air assisted foam mat dried avocado powder (CD) for wettability and solubility times. The changes in ash content, pH, water holding capacity, bulk and tapped densities, Carr Index, and Hausner Ratio values followed a quadratic trend depending on both drying temperature and microwave power. The first variable explained 53.63%, and the second variable explained 21.08% of the variance for a total of 74.71% by Principal Component Analysis.**

***Keywords*— Avocado; Egg white; Foam mat drying; Functional properties; Powder properties.**

I. INTRODUCTION

Longer shelf-life, product diversity, lower packaging area, packaging and transportation costs, mixing and dosing advantages, etc. are the reasons for the popularity of food powders (Caliskan and Dirim, 2016). Food powders can be obtained by several types of drying techniques such as convective, freeze, microwave, spray drying, etc. Another promising technique for obtaining food powders is foam mat drying because of being suitable for all types of liquids and semi-liquids, having a high surface area which results in rapid drying, retention of nutritional and organoleptic characteristics, being cost-effective, obtaining powder with desired reconstitution properties, etc. (Kudra and Ratti, 2006, Sangamithra *et al.*, 2015). Foam mat drying technique provides drying of foams of liquid or semi-liquid foods such as puree in the presence of foaming and/or stabilizing agents using several drying techniques such as microwave, convective, freeze-drying, etc. (Rajkumar *et al.*,2007). The quality of food powders depends on the selection of the foaming method, agent, stabilizer, and time, drying method and conditions (Sangamithra *et al.*, 2015). Whole egg and egg-derived proteins are generally used in the food industry due to their foaming, emulsifying, gelling properties, etc. (Ayadi *et al.*, 2008). Egg white powder was used as a foaming agent and foaming stabilizer at several studies such as foam mat convective drying of Cantaloupe (Salahi *et al.*, 2015), foam mat freeze-drying of apple juice (Raharitsifa and Ratti, 2010), foam mat drying of sour cherry concentrate (Abbasi and Azizpour, 2016), etc. Therefore, in this study egg white was chosen for foaming agent due to its foaming properties. In many studies, it was observed that the drying process, which is the last step of the foam drying process, was carried out in convective dryers (Falade *et al.*, 2003, Kadam and Balasubramanian, 2011, Abbasi and Azizpour, 2016, Shaari *et al.*, 2017, Varhan *et al.*, 2019). It may be due to the simplicity of dryer construction and ease of operation of convective dryers (Araya-Farias and Ratti, 2009). In recent years, the microwave drying process was also performed as a final step of foam mat drying (Qadri and Srivastava, 2017, Varhan *et al.*, 2019, Çalışkan Koç and Çabuk, 2019, Qadri *et al.*, 2020). Microwave drying has also several advantages such as having short drying time, ease of process control, energy-saving, and uniform heating (Alibas, 2007). For this reason, in this study, the convective and microwave drying techniques were chosen for the foam mat drying process.

Avocado (*Persea Americana* Mill.) is a seasonal, tropical, widely grown, and consumed fruit that contains monounsaturated fatty acids, dietary fiber, essential nutrients, and phytochemicals (lutein, phenolic antioxidants, and phytosterols) (Fulgoni *et al.*, 2013). The avocado powder can be useful for off-season for several purposes such as coloring agent, cosmetic industry, etc. There are few studies on the drying of avocados such as heat pump drying (Ceylan *et al.*, 2007) and convective drying (Tsami and Katsioti, 2000). From the authors' knowledge, there is a paucity of the literature producing foam mat dried avocado powder and investigating the effect of foam mat drying processes and conditions on the physical, functional, and powder properties of the avocado powder. For this reason, this study aimed to produce avocado powder using hot air and microwave-assisted foam mat drying techniques and to determine the effect of different drying techniques and conditions (drying temperature and microwave power) on the weight loss of avocado puree, drying time, physical, functional, and powder properties of avocado powders. In addition, the changes in the physical, functional, and powder properties of avocado powders were also modeled in this study.

II. METHODS

A. Materials

The mature avocados and commercial pasteurized liquid egg whites were obtained from a supermarket in Alanya and Anako Egg and Products Food Industry. Exp. Imp. and Trade Inc., Ankara, Turkey, respectively. The mature avocados were washed, peeled, and the puree was obtained using home-type kitchen blender (1000W power, SHB 3107, Sinbo, Turkey).

B. Foam Preparation

150g of avocado puree and 10, 20, and 30% (by weight) of liquid egg white as a foaming agent were added to the glass beaker at room temperature. In order to obtain avocado puree foam, the home type kitchen blender (1000W power, SHB 3107, Sinbo, Turkey) was used at three different whipping time as 2, 3, and 4 minutes. The desired foam structure and properties were not observed for avocado puree (150g) + 10% and 20% liquid egg white. The avocado puree (150g) + 30% liquid egg white (45g) which was whipped 3 min showed the most stable foam properties such as foam volume, density, stability, etc (Data for other trials was not given.). The total amount of avocado foam was 20.00±0.20g for each drying experiment. Samples were placed flat as a slab (10cm diameter and 2mm thickness). For this reason, the drying took place from one side.

C. Hot air and microwave-assisted foam mat drying techniques

The avocado foam containing egg white was dried in a convective oven (Memmert, UF 110, Germany) at three different drying temperatures (60, 70, and 80°C) and 20% ventilation rate. The weight loss was measured every 5 min until the constant weight was reached. Domestic digital microwave oven (Arçelik MD574, Turkey) with the technical feature of 230-240V, 50 Hz, 700W output power, 1200W total power, and 20liter volume at 3 different microwave output power settings (120W, 460W, and 700W) was used for microwave drying experiments. Samples were removed periodically (at 30s intervals for 120W microwave power and 10s intervals for 460W and 700W microwave powers) from the microwave oven and weighed.

All experiments were completed when the change in the mass of the samples dropped to 0.01 (g) between the two measurements. The avocado powder was obtained by grinding the dried material with a mortar and packaged in aluminum polythene bags for further analysis.

D. Analysis

The foam density, foam expansion, foam stability, and drainage volume were determined according to the methods given by Bag *et al.* (2011), Rajkumar *et al.* (2007), and Sauter and Montoure (1972), respectively.

The moisture and ash contents of the avocado puree powders were determined according to AOAC (2000) and AOAC (2005), respectively. The pH values were measured using pH meter (SevenExcellence S 400 Mettler Toledo AG, China). The water and oil holding capacities of avocado puree powders were determined according to Stone *et al.* (2015).

Bulk and tapped densities, flowability (Carr Index: CI) and cohesiveness (Hausner Ratio: HR) values, solubility and wettability time analysis were performed according to the procedure described by Jinapong *et al.* (2008), Goula and Adamopoulos (2008), and Gong *et al.* (2008), respectively.

In order to determine the relationship between physical and powder properties of avocado foam powder and microwave power and drying temperature; linear ($y = ax + b$), power ($y = ax^b$), logarithmic ($y = a\,ln(x) + b$), and quadratic ($y = ax^2 + bx + c$) functions were fitted to experimental data (SPSS 20.0, SPSS Inc., Chicago, IL, U.S.A). The goodness of fit was determined using the coefficient of determination (R^2) that can be described by the equation given by Qadri *et al.* (2020). All experiments were performed in duplicates and measurements were performed in triplicates. All data points shown in graphs represent the mean of triplicate analysis. Statistically significant differences between samples were determined using ANOVA (analysis of variance, $\alpha = 0.05$). Significant differences are indicated by different letters when the p-value was below 0.05. Principal Component Analysis (PCA) was conducted with XLSTAT version 2010 (Addinsoft, New York, NY).

III. RESULTS

A. Foam Properties

The larger surface area which is important for faster evaporation rate during foam mat drying can be obtained by incorporation of a higher amount of air. For this reason, lower foam density values are desired for obtaining a higher surface area which helps to accelerate the movement of water removal during drying (Falade *et al.,* 2003, Ng and Sulaiman, 2018). In this study, the lowest foam density (1040.58±176.98kg/m^3) and the highest foam expansion ratios (9.61±0.12%) were observed for the avocado puree with 30% egg white. Similarly, Falade *et al.* (2003) and Ng and Sulaiman (2018) reported that the foam density values of cowpea paste and beetroot pulp decreased according to the increasing concentration of foaming agents. The foam stability during drying is important for increasing the drying rate and porosity of obtained powder and decreasing drying time (Abbasi and Azizpour, 2016). The most stable foam (97.86±1.10%) was also observed for the avocado puree with 30% egg white. The drainage volume of the avocado puree with 30% egg white was measured to be as 0.42±0.01mL. Similarly, Shaari *et al.* (2017) reported that an increase in egg albumen concentration (5%, 10%, and 20% by weight) resulted in an increase in the foaming ability and expansion and a decrease in the foam density.

B. Drying Time and Behavior

The changes in the weight of avocado puree foam depending on drying time is shown in Fig. 1 (a and b). According to Fig. 1, it can be stated that the avocado puree foam showed a similar trend at all drying temperatures. Half of the weight of avocado puree foam removed in 50,

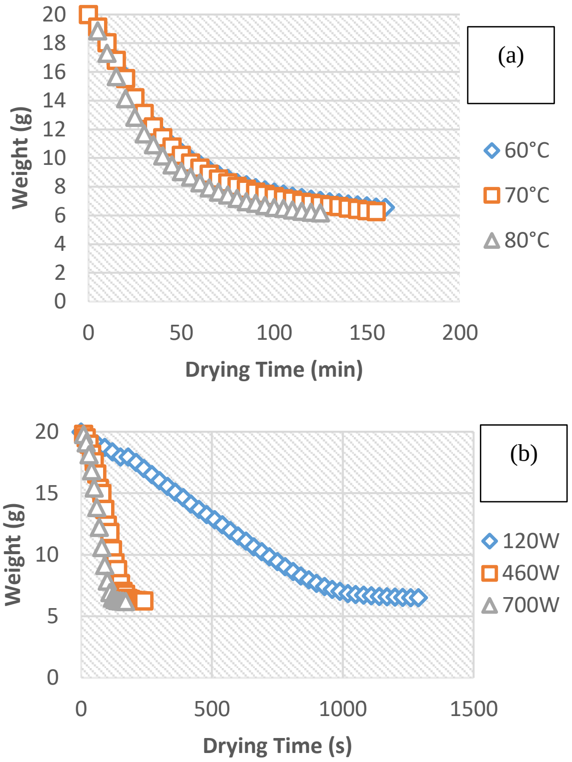

Figure 1: The changes in the weight of avocado puree during foam mat drying (a: Hot air assisted foam mat drying, b: Microwave-assisted foam mat drying).

50, and 40 min for 60, 70, and 80°C drying temperatures, respectively. In microwave-assisted foam mat experiments, the required times to remove the half of the weight of avocado puree foam were 14, 2, and 1.33 min for 120, 460, and 700W microwave powers, respectively. Although half of the weight was removed in the early stages of drying, the total drying times of samples were higher more than two times of these values due to the falling rate period. The total drying times were found to be 160, 155, and 125 min for 60, 70, and 80°C drying temperatures, respectively. It can be stated that the drying time of the avocado foam significantly decreased with increasing drying temperature ($p < 0.05$). Similar results were also obtained by Abbasi and Azizpour (2016) and Kadam and Balasubramanian (2011). Significantly lower drying times were observed for the microwave-assisted foam mat dried avocado powder ($p < 0.05$) and the drying times of avocado purees were 21.50, 4.20, and 2.80 min for 120, 460, and 700W microwave powers, respectively. Different drying techniques have different advantages and microwave drying generally used for high heat transfer rate, low drying time, energy cost, etc. According to the results it can be stated that the microwave drying can be decreased the drying time of avocado puree foam around 93.50% compared to hot air drying (This value was calculated using average drying time values.). Similarly, Varhan *et al.* (2019) reported that the required time to reach the final moisture content of fig foam for hot air drying was significantly higher compared to microwave drying. Qadri and Srivastava (2014) reported that the required times to reach the final moisture content for tomato pulp foam (10mm thickness) were 110min for hot air drying at (45°C), and 15, 12, and 10min for 480W+45°C, 640W+45°C, and 800W++45°C microwave+hot air drying, respectively. According to the results, it can be concluded that the application of microwave energy as a final step of foam mat drying significantly decreases the drying time by increasing the drying rate.

C. Physical and functional properties

Some physical and functional properties of avocado powders are given in Tables 1 and 2, respectively. The moisture content of avocado puree was 69.33±0.32% (wet basis). Significantly lower moisture content values were observed for the microwave-assisted foam mat dried avocado powders except for 120W microwave power ($p < 0.05$). The moisture content values of hot air and microwave-assisted foam mat dried avocado powders significantly decreased when the drying temperature and microwave powder increased (60°C to 70°C and 120W to 460W $p < 0.05$), however, further increase in the drying temperature and microwave power resulted in an insignificant decrease (70°C to 80°C and 460W to 700W, $p \geq 0.05$). It may be due to higher heat and mass transfer rates at higher drying temperatures and microwave powers. The decreases in the moisture content values were found to be suitable for power function for hot air assisted foam mat dried samples ($y = 11.914x^{-0.568}$, $R^2 = 0.9886$) and logarithmic function for microwave-assisted foam mat dried samples ($y = -2.374ln(x) + 5.8724$, $R^2 = 0.8515$). Different heat transfer mechanism of drying techniques may be the reason for different moisture content values and trends.

The ash content of avocado puree was measured to be 4.96±0.44% (dry basis, db). The ash content of microwave-assisted foam mat dried avocado powders decreased with microwave power, however, this decrease was found insignificant ($p \geq 0.05$). Higher ash content values were observed for the hot air assisted foam mat dried avocado powders compared to microwave-assisted foam mat dried avocado powders ($p < 0.05$). The changes in ash content of avocado powders followed a quadratic trend both temperature ($y = -0.9302x^2 + 3.641x + 2.2453$, $R^2 = 0.9999$) and microwave power ($y = -0.0818x^2 + 0.2222x + 3.6205$, $R^2 = 0.9999$). The pH values of avocado powders ranged between 7 and 8 which can be accepted as in the neutral and alkali range. The high pH values of powders may be due to the high pH value of egg white which is in the alkali range (around 9). Similar findings were also obtained by Abbasi and Azizpour (2016) and Kadam *et al.* (2011). The changes in pH values followed a quadratic trend for both hot air ($y=0.0825x^2-0.3575x+8.295$, $R^2=0.9999$) and microwave-assisted foam mat dried samples ($y = 0.0925x^2 - 0.4475x + 8.195$, $R^2 = 0.9999$). The pH values of samples generally decreased depending on the increasing temperature and microwave power. This decrease was found to be significant for hot air assisted foam mat dried avocado powders ($p<0.05$). Abbasi and

Table1. Some physical properties of the foam mat dried avocado powder ($n = 3$)

Sample	Moisture Content (%, wb)	Ash Content (%, db)	pH
CD-60°C	12.09±1.94[c]	4.95±0.01[b]	8.02±0.01[e]
CD-70°C	7.73±0.68[b]	5.81±0.42[b]	7.91±0.01[c]
CD-80°C	6.54±0.05[b]	4.80±0.49[b]	7.97±0.01[d]
MW-120W	6.10±0.84[b]	3.76±0.33[a]	7.84±0.01[b]
MW-460W	3.60±0.45[a]	3.74±0.10[a]	7.67±0.01[a]
MW-700W	3.66±0.14[a]	3.55±0.19[a]	7.69±0.01[a]

[a-e] Show a significant difference between the means of the samples (in the same column, $p < 0.05$).

Table 2. Functional properties of the foam mat dried avocado powder (n=3)

Sample	*Water Holding Capacity (%, wb)*	*Oil Holding Capacity (%, wb)*
CD-60°C	171.50±3.54[c]	58.50±0.71[a]
CD-70°C	107.00±16.97[a]	73.50±7.78[b]
CD-80°C	115.50±4.95[ab]	94.00±1.41[c]
MW-120W	143.50±17.68[bc]	84.00±7.07[bc]
MW-460W	157.50±17.68[c]	87.00±2.83[bc]
MW-700W	142.50±3.54[bc]	91.00±7.07[c]

[a-e] Show a significant difference between the means of the samples (in the same column, $p < 0.05$).

Azizpour (2016) reported that when the drying temperature increased from 50 to 65ºC, the pH values of the sour cherry powders raised, however, a further increase (65 to 80 ºC) caused an opposite effect. Similarly, in this study, the hot air temperature was higher than 60 ºC. It may be concluded that the higher drying temperatures resulted in lower pH values.

Water holding or absorption capacity is related to the capability of dry food to absorb water (Barbosa-Cánovas and Juliano, 2005). The water holding capacity values of avocado powders followed a quadratic trend ($y = 36.5x^2 - 174x + 309$, $R^2 = 0.9999$ for CD and $y = -14.5x^2 + 57.5x + 100.5$, $R^2 = 0.9999$ for MW), however, the oil holding capacity values changed linearly ($y = 17.75x + 39.833$, $R^2 = 0.9921$ for CD and $y = 3.5x + 80.333$, $R^2 = 0.9932$ for MW). The highest water holding capacity and lowest oil holding capacity values that are desired were observed for hot air assisted foam mat dried avocado powder at 60°C. The water holding capacity values of hot air assisted foam mat dried avocado powders significantly decreased when the drying temperature increased (60°C to 70°C, $p<0.05$), however, further increase in drying temperature resulted in an increase (70°C to 80°C, $p \geq 0.05$). The opposite effect was observed for water holding capacity values of microwave-assisted foam mat dried avocado powders, however, these changes were found to be insignificant ($p \geq 0.05$). The oil holding capacity values of both hot air and microwave-assisted foam mat dried avocado powders increased according to increasing drying temperature and microwave power ($p < 0.05$).

D. Powder Properties

The determination of powder properties such as density, flow characteristics, reconstitution behavior, etc. of food powders is important for manufacturers and end-user for packaging, handling, measuring, transportation, bag filling, emptying, storage, dosing, mixing, conditioning, etc. (Caliskan and Dirim, 2016). The powder properties of foam mat dried avocado puree foam powders are presented in Table 3. The bulk density values of hot air and microwave-assisted foam mat dried avocado powders ranged between 398.02-400.00 kg/m^3 and 394.10-398.02 kg/m^3, respectively. These results were also in line with those obtained by Varhan *et al.* (2019) who reported the bulk density values of hot air and microwave-assisted foam mat dried fig powders ranged between 0.36 and 0.50 g/cm^3 and 0.34 and 0.47 g/cm^3, respectively. In addition, researchers reported that bulk density values of microwave-assisted foam mat dried fig powders slightly lower than hot air assisted foam mat dried fig powders. Similar results were also obtained in this study. At the high microwave powers, the solid structure formed before the air gets out from the foam. It may be the reason for lower bulk density values of microwave-assisted foam mat dried avocado powder (Varhan *et al*., 2019). According to the results of statistical findings, it can be stated that the different drying techniques and conditions did not cause a significant effect on the bulk density values of avocado powder ($p \geq 0.05$). Ng and Sulaiman (2018) reported that the bulk density for beetroot powder ranged between 0.80 and 0.83 g/cm^3 and the difference in types and concentrations of foaming agents did not affect the bulk density values. The changes in tapped densities values of CD-60°C and CD-70°C and MW-120W and MW-460W were found to be insignificant ($p \geq 0.05$), however, a further increase in the drying temperature resulted in a significant decrease ($p < 0.05$). In contrast, an increase beyond 460W microwave power resulted in a significant increase ($p < 0.05$). Higher bulk and tapped density values generally observed for the hot air assisted foam mat dried avocado powders. Higher bulk density values are generally preferred for lowering the transportation, packaging, storage, etc. costs (Çalışkan Koç and

Table 3. Powder properties of the foam mat dried avocado powder (n=3)

Sample	Bulk Density (kg/m^3)	Tapped Density (kg/m^3)	Flowability (Carr Index)	Cohesiveness (Hausner Ratio)	Wettability Time (s)	Solubility Time (s)
CD-60°C	400.00±0.00[a]	571.43±0.00[b]	30.00±0.00[b]	1.43±0.00[b]	19.00±1.41[b]	40.50±0.71[c]
CD-70°C	400.00±0.00[a]	571.43±0.00[b]	30.00±0.00[b]	1.43±0.00[b]	23.50±0.71[c]	37.00±1.41[b]
CD-80°C	398.02±2.80[a]	535.71±10.51[ab]	25.40±1.51[ab]	1.35±0.02[ab]	25.50±0.71[d]	27.50±0.71[a]
MW-120W	394.10±2.75[a]	500.00±0.00[a]	20.79±1.13[a]	1.27±0.01[a]	13.50±0.71[a]	34.00±1.41[b]
MW-460W	394.10±2.75[a]	500.00±0.00[a]	21.18±0.55[a]	1.27±0.01[a]	43.50±0.71[f]	53.50±2.12[e]
MW-700W	398.02±2.80[a]	571.43±0.00[b]	30.35±0.49[b]	1.44±0.01[b]	30.00±0.00[e]	46.00±1.41[d]

[a-e] Show a significant difference between the means of the samples (in the same column, $p < 0.05$).

Dirim, 2018). The bulk ($y = -0.9901x^2 + 2.9703x + 398.02$, $R^2 = 0.9999$ for CD and $y = 1.9608x^2 - 5.8824x + 398.02$, $R^2 = 0.9999$ for MW) and tapped density ($y = -17.857x^2 + 53.571x + 535.71$, $R^2 = 0.9999$ for CD and $y = 35.714x^2 - 107.14x + 571.43$, $R^2 = 0.9999$ for MW) values of avocado powders followed a quadratic trend. Shaari *et al.* (2017) reported that an increase in the egg albumen concentration resulted in higher bulk density values of pineapple powder due to the higher molecular weight of proteins. The high content of egg white may be the reason for the high bulk density values of avocado powders.

The flow characteristics of foam mat dried avocado powder were evaluated in terms of Carr Index and Hausner Ratio which indicates the flowability and cohesiveness, respectively. Similar to results of tapped density values, the changes in CI and HR values of CD-60°C and CD-70°C and MW-120W and MW-460W were found to be insignificant ($p \geq 0.05$), however, a further increase in the drying temperature resulted in a significant decrease ($p < 0.05$), whereas a further increase in the microwave power resulted in a significant increase ($p < 0.05$). According to obtained values, it can be stated that hot air assisted foam mat dried avocado powders (Carr Index: fair level and Hausner Ratio: intermediate and high levels) have poor flow characteristics compared to microwave-assisted foam mat dried avocado powders (Carr Index: fair level and Hausner Ratio: intermediate and high levels) except for MW-700W. It may be due to higher moisture content values of hot air assisted foam mat dried avocado powders which increase the cohesion between powder particles, resulting in lower flowability. The Carr Index ($y = -2.302x^2 + 6.9059x + 25.396$, $R^2 = 0.9999$ for CD and $y = 4.389x^2 - 12.779x + 29.182$, $R^2 = 0.9999$ for MW) and Hausner Ratio ($y = -0.0415x^2 + 0.1246x + 1.3455$, $R^2 = 0.9999$ for CD and $y = 0.0835x^2 - 0.2504x + 1.4357$, $R^2 = 0.9999$ for MW) values of avocado powders followed a quadratic trend. The high oil content of avocado powders may be the reason for poor flow characteristics. In order to improve the flow properties of avocado powders, avocado oil can be removed, several food-grade additives may be added or agglomeration process may be applied to the powders.

The wettability and solubility times of avocado powders were found to be lower than 55s. According to the fast wettability and solubility times of avocado powders, it can be stated that all samples dissolves or disperses more readily and a higher percentage in the water. It may be due to choosing the most stable foam which includes 30% of egg white. The more stable foam structure during the hot air and microwave drying process, the more bubbles will remain stable during the whole drying process. Therefore, bubbles cause an increase in the porosity of the powder and its solubility (Abbasi and Azizpour, 2016). The wettability times of avocado powders generally and significantly increased with temperature and microwave power, however, the opposite effect was observed for solubility times of powders ($p < 0.05$). The changes in the wettability and solubility times of powders followed a linear trend ($y = 3.25x + 16.167$, $R^2 = 0.9530$, and $y = -6.5x + 48$, $R^2 = 0.9337$) with temperature, whereas a quadratic trend was observed ($y = -21.75x^2 + 95.25x - 60$, $R^2 = 0.9999$ and y=-$13.5x^2 + 60x - 12.5$, $R^2 = 0.9999$) for microwave power. Although the lowest wettability time was observed for MW-120W, the wettability times of hot air assisted foam mat dried avocado powder were found to be generally and significantly lower compared to microwave-assisted foam mat dried powders ($p < 0.05$). In addition, the solubility times of hot air assisted foam mat dried avocado powders were generally and significantly lower compared to microwave-assisted foam mat dried powders ($p < 0.05$). Lower wettability and solubility times of hot air assisted foam mat dried avocado powder may be due to a higher moisture content of samples. Abbasi and Azizpour (2016) reported that higher drying temperatures resulted in faster collapsing of sour cherry bubbles which reduced the porosity and solubility of the powder. According to this explanation, it can be stated that a higher heat transfer rate at the high microwave power which reduced the porosity may be the reason for higher wettability and solubility times of the avocado powders. The samples (CD-60ºC) which have the lowest wettability time (19s) has the highest moisture content value (12.09%), and microwave-assisted foam mat dried samples have higher wettability times which also have lower moisture content. According to this finding, it can be stated that the moisture content and wettability time of foam mat dried avocado powders have an inversely proportional relationship. However, the directly proportional relationship was observed for the moisture content and solubility time of hot air assisted foam mat dried avocado powders.

Principal component analysis (PCA) allows to perform a complex statistical evaluation of all gained data and to distinguish different groups on the basis of their properties (Sledz *et al.*, 2017). The relationship between foam mat dried avocado samples with the different drying methods (hot air and microwave-assisted foam mat dryings) and physical, functional, and powder properties were evaluated by PCA (Fig. 2). The first variable (F1), which were mostly connected with bulk density (factor loadings 0.946), explained 53.63%, and the second variable (F2), which were mostly connected with solubility time (factor loadings 0.784), explained 21.08% of the variance for a total of 74.71%. Hot air assisted foam mat dried avocado powder were positively associated with F1, whereas, microwave-assisted foam mat dried avocado powders were negatively associated with F1. Although, the avocado powders which were dried at CD-60ºC, CD-70ºC, MW-460W, and MW-700W were placed in the positive F2 direction, the avocado samples which were dried at CD-80ºC and MW-120W negatively associated. According to PCA, it can be stated that drying techniques (hot air and microwave-assisted foam mat dryings) were separated by F1, however, both different drying techniques and conditions (temperature and

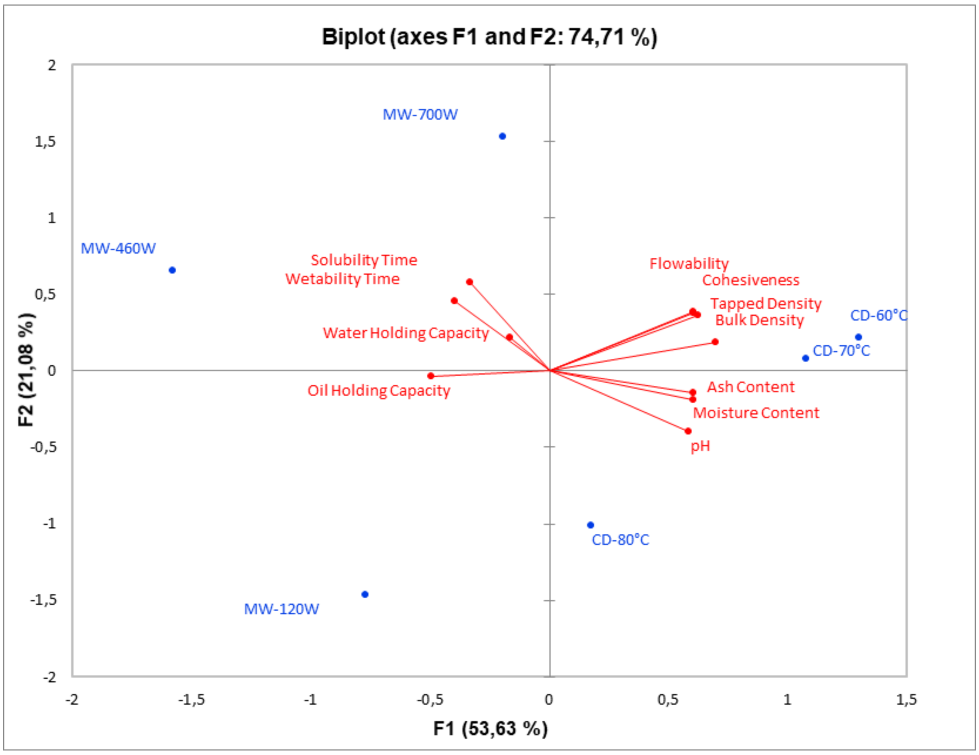

Figure 2: The results of principal component analysis.

power) were separated by F2. On the positive sides of F1 and F2, CD-60ºC and CD-70ºC were associated with the bulk (bulk and tapped densities) and flow properties (flowability and cohesiveness). Despite this fact, it can be stated that bulk and flow properties strongly affect samples dried at CD-60ºC and CD-70ºC. It means that this variable had a very big impact on the deviation from the average value in the case of these samples. On the positive side of F1 and the negative side of F2, CD-80ºC was correlated with physical properties (moisture and ash contents and pH). On the negative side of F1 and the positive side of F2, MW-460W and MW-700W were correlated with reconstitution properties (wettability and solubility times) and water holding capacity. On the negative direction of F1 and F2, MW-120W was correlated with oil holding capacity value.

IV. CONCLUSIONS

In this study, it was observed that hot air and microwave-assisted foam mat drying processes are suitable to obtain avocado puree powder. The physical, functional, and powder properties of the foam mat dried avocado powders were generally and significantly affected by both the drying techniques and conditions (temperature and microwave power $p < 0.05$). Microwave-assisted foam mat dried avocado powder have less drying time, moisture, ash, and pH contents, bulk and tapped densities, CI and HR values than hot air assisted foam mat dried avocado powder ($p < 0.05$). Comparatively better results were obtained for the hot air assisted foam mat dried avocado powder for wettability and solubility times. The first variable explained 53.63%, and the second variable explained 21.08% of the variance for a total of 74.71% by PCA. The possible uses of foam mat dried avocado powders in food systems, chemical composition, and storage potential should be studied in future studies.

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