Investigating the physicochemical properties of permeate-based orange beverage powder prepared by foam mat drying method

Azita Nemati (Azita.Nemati@yahoo.com)
Sari Agricultural Sciences and Natural Resources University https://orcid.org/0000-0002-9480-6704
Ali Motamedzadegan
Sari Agricultural Sciences and Natural Resources University
Jafar M. Milani
Sari Agricultural Sciences and Natural Resources University

Research Article

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Investigating the physicochemical properties of permeate-based orange beverage powder prepared by foam mat drying method

Azita Nemati*[1]. Ali Motamedzadegan[1]. Jafar M.Milani[1]

[1] Department of Food Science and Technology, Faculty of Agricultural Engineering, Sari Agricultural Sciences and Natural Resources University, Km 9 Farah Abad Road, Sari, Iran

Correspondence: Azita Nemati

EMAIL: Azita.nemati@yahoo.com, **TEL**: +98-911-1947955

Abstract

Permeate is the by-product of the ultrafiltration in a kind of cheese making process, and as a waste disposal of dairy companies, was applied in production of orange beverage. The purpose of this study was to investigate the possibility of using the foam mat drying method to prepare permeate-based orange beverage powder while maintaining its physicochemical properties. In order to prepare the beverage foam, the desired amounts of egg white 4% and basil gum solution 0.2% were added to the orange beverage and were mixed for 6 minutes. Drying was performed under different temperatures (45, 65, and 80°C) and microwave power (360, 600 and 900 W) and freeze-dryer with (3 mm) thickness. Some properties of the beverage powder including moisture content, water activity, solubility, water binding capacity, rehydrating the powder, hygroscopy, flowability, porosity, pH, color, DSC, and FTIR characteristics were investigated. It was observed that freeze dried beverage powder had the maximum solubility and highest flowability.

Keywords: Egg white, Basil gum, Beverage powder, Foam mat drying, waste product.

Statement of Novelty

In this study Production of orange beverage powder, especially based on local products and with the aim of optimal use of permeate was evaluated, and different drying condition with oven (45, 65, and 80) temperatures and microwave power (360, 600 and 900) and freeze-dryer with (3 mm) thickness.

1. Introduction

Production of powdered beverage, especially based on local products and with the aim of optimal use of waste, is one of the research fields considered by the food industry. Beverage powder is more economical than ready-to-drink beverage, due to its weight, packaging, ease of transportation and use, and higher shelf life. In addition, the physical state of the powder makes it possible to use it as a stable natural compound and easy to use in many food, pharmaceutical and health products. However, drying beverage is not an easy task [1].

Milk permeate, which is the by-product of ultrafiltration process of milk, has been regarded as a waste product. It is a rich source of lactose and nutraceutical ingredients such as the essential amino acids and soluble proteins, immunoglobulin, lactoferrin, lactoperoxidase, vitamins, growth factors, and minerals[2].

Basil with the scientific name (Ocimum basilicum) is from the genus of Mint. This plant is found in many parts of the world, especially in the tropics of Asia, Africa and South America. Basil seeds contain large amounts of hydrocolloids with remarkable rheological properties that make it comparable to other commercial hydrocolloids. The seeds of this plant contain a heteropolysaccharide structure including glucomannan, xylan and glucan. Basil seed gum is classified as anionic gum with pH = 7.78. This gum contains 63.79% carbohydrates and 32.1%

protein. Glucose, galactose and mannose are 6.29, 1.16, 9.8% of the major constituent sugars respectively and potassium with 64.2% is the major ions in this gum [3].

Albumin is the major component of egg white protein (about 54%) and its molecular weight is about 42.7 kDa. This protein is widely used in the food industry due to its emulsifying properties and foam production [4].Albumin is a heterogeneous protein system in which protein-protein interactions occur during the foaming process. The mechanism of egg white foam production is due to the surface denaturation of albumin proteins at the liquid-air surface and the foam stability mechanism is related to the insolubility of albumin. The most important performance of albumin in the foam is to increase the storage time of a large volume of air in the system [5].

Foam mat drying is a method that has been considered by researchers in recent years. Decreased density, increased porosity, better rehydration, and greater uniformity are the salient features of food that is dried in this way [6].

The advantages of the foam mat drying process include simplicity, fast speed of drying at lower temperatures, less expensive processing compared to other drying methods, maintaining nutritional and sensory quality. Other advantages of this method include being suitable for all types of liquid, semi-liquid, heat-sensitive, sticky and viscous foods. Also, there is no burning taste in the product produced by this method due to the minimal heat damage to the product. The high drying speed is due to the increase in the surface of the substances by the combination of air and gas and the formation of a porous structure, which gives high quality and immediate properties to the dried products. Dried powders are easily absorbed by water, are fast dissolving and are used as a starter in the production of products such as food condiments, soups, sauce powders, snacks, desserts, baby food, etc [7,8].

In 2017, Affandi et al. produced beverage powder of Nigella Sativa by using foam mat drying method. For this purpose, different amounts of egg whites (2.5, 8.75 and 15% w / w), methyl cellulose (0, 0.5 and 1% w / w), stirring time of 2, 5 and 8 minutes, foam thickness of 1, 2 and 3 mm and drying temperature of 50-70 ° C were examined. The results showed that the optimal process conditions for the prepared foam sample was 15% egg white 0.69% methyl cellulose, stirring time of 8 minutes and the foam thickness of 2 mm at 60 °C [9].

In 2015, Abbasi et al. investigated the physicochemical properties of cherry powder by foam mat drying method. For this purpose, different amounts of egg white powder (1, 2 and 3 g / 100g) and methyl cellulose (1, 1.5 and 2 g / 100g) and drying temperature (50, 65 and 80 °C) on the properties of cherry powder were examined. The results showed that increasing the concentration of methylcellulose and egg white, could decrease drainage volume, foam density, browning index and drying time. The dried samples at 65 °C showed the highest solubility [10]. The purpose of this study was to investigate the possibility of using the foam mat drying method to prepare permeate-based orange beverage powder while keeping its quality attributes.

2. Materials and methods

2.1 Materials

The raw materials used in this research include orange concentrate (Noush Company Mazandaran), permeate powder (Kaleh factory of Amol), basil seeds, egg white powder and sugar were prepared from a store in Sari, Iran.

2.2 Gum extraction

Basil seeds are first placed in distilled water with a pH of 7 and the water-to-grain ratio of 30 to 1(vol/weight). Separation of gum from seeds is done using the Pars Khazar juicer (JC-700P model, Iran). It was kept in the freezer at -20 ° C and dried by the freeze dryer (VaCo 5, Zirbus

technology, Germany) at -50 ° C for 24 hours and after powdering, it is used for experiments. The gum solution was made by adding the required amounts of gum powder by weight to distilled water to create a concentration of 2% and was mixed with a magnetic stirrer (MS300HS model, Korea). The gum solution was then kept in the refrigerator temperature (4 °C) for 18-24 hours to fully hydrate the gum.

2.3 beverage preparation

The ingredients, including permeate and orange concentrate, sugar were each weighed in terms of °Brix which provided 50% of the total Brix of the beverage and specified (w/w) ratio until a final °Brix of 12 was weighed with a certain percentage and the compounds were mixed by magnetic stirrer until they were completely dissolved (Nemati et al., 2020).

2.4 Preparation of foam samples

According to the design of the study, the desired amounts of egg white 4% and basil gum solution 0.2% were added to the orange beverage and the mixture was stirred with a home electric mixer (GOSONIC, GHM-818 model, China), at the highest speed at room temperature for 6 minutes. Drying was performed under different oven treatments with different temperatures (45, 65 and 80), microwave power (360, 600 and 900) and freeze-dryer with one thickness (3) mm.

2.5 Evaluating the properties of the beverage powder

2.5.1 Moisture content

The sample was poured into plates that had already reached a constant weight and weighed with digital scale (HS-300S model, Germany) with an accuracy of 0.001, and then the plates were placed in the oven at 105° C until they reached a constant weight. The samples were then placed inside a desiccator until they were cool. The samples were then weighed and the

moisture content was calculated from the weight difference between the samples before and after the drying process and expressed in terms of dry matter (AACC, 2000).

2.5.2 water activity

Powder samples were placed in the cell of the device (Novasina model: lab swift-aw) and its water activity was reported after 30 minutes when it was remaining constant at room temperature (24.5 ± 0.5° C).

2.5.3 Solubility

One gram of the sample was dissolved in 100 ml of distilled water at 25° C, then mixed for 10 minutes by placing on a stirrer, and also separated by centrifugation at 4000 rpm for 10 minutes. Then 25 ml of the supernatant solution it was placed in an oven at 105° C, then the remaining solids were weighed after drying and the following formula was used to calculate the solubility [7].

Eq. (2) $$\mathbf{S=\frac{m_2-m_1}{0/25}}$$

$\boldsymbol{m_1}$*:* plate weight and $\boldsymbol{m_2}$**:** plate weight containing sample after reaching constant weight.

2.5.4 Water binding capacity

4 grams of the sample was weighed in 30 ml of distilled water into 50 ml Falcon tubes, then vortexed for 4 minutes and then centrifuged at 4000 rpm for 20 minutes. The upper transparent layer was discarded and the Falcon was re-weighed. The water binding capacity was calculated according to the following formula

Eq. (3) $$\mathbf{WBC=\frac{A-B}{c}}$$

135 ***A*** = The amount of water added to the beverage powder before centrifugation in grams

136 ***B*** = The amount of water extracted from the beverage powder after centrifugation in grams

137 ***c*** = sample weight in grams

138 **2.5.5 Rehydrating the powder**

139 The amount of 5 grams of the sample was immersed in 50 ml of distilled water for 60 minutes
140 and after filtering, the amount of rehydration of the samples was calculated using the following
141 equation [10].

142 **Eq. (4)** $\textbf{Rehydration} = W_2/W_1$

143 In this equation, W_2 is the weight of the discharged material and W_1 is the weight of the dried
144 material in grams.

145 **2.5.6 Hygroscopy**

146 To measure the moisture content of the produced powders, 1 gram of the sample powder was
147 placed in a container impermeable to moisture, containing a saturated solution of sodium
148 chloride (RH =75%) at 25 °C. After one week and reaching a constant weight, the moisture
149 content of the samples was calculated from the equation (5) [12].

150 **Eq. (5)** $\textbf{Hygroscopicity} = \Delta m/(m+m_1)/\ 1+ (\Delta m/m)$

151 **Δm:** increase in powder weight, **m:** initial mass of powder

152 **2.5.7 Powder flowability**

153 The flow rate of the powder was calculated by the Carr Index and the Hausner ratio through
154 the following equations.

155 **Eq. (6)** $CI = \rho_T - \rho_B / \rho_T \times 100$

Eq. (7) $HR = \rho_T / \rho_B$

In these relationships, ρ_B is bulk density and ρ_T is tapped density [13].

2.5.8 Porosity

To obtain this index, 2 grams of each sample was poured into a pycnometer and filled with a specified volume of petroleum ether. The use of petroleum ether is due to the penetration between the smallest external cavities attached to the particle surface (without dissolving the material). Particle density was obtained from the ratio of powder weight to powder volume and based on Equation (8), the amount of bulk porosity was obtained by measuring the particle density to bulk density. The porosity of the beverage powder was calculated by the relationship between the tapped density (ρt) and the particle density (ρp) according to the following formula.

Eq. (8) $\varepsilon = \rho_p - \rho_t / \rho_p \times 100$

2.5.9 pH

First, the samples were mixed with distilled water in a ratio of 1 to 10 and then the pH of each solutions was measured using a pH meter (CP-511 model, Poland) at 25 °C [14].

2.5.10 Colorimetry

Color analysis was performed using image processing technique. Imaging of the samples was done using the IMG-Pardazesh Cam-System colorimeter and the images were separated from the background image in the next step,the image were converted to L* a* b*using the color space converter plugin by Image J software, and the average for each component was calculated according to Eq. 9, 10, 11. [14].

Eq. (9) $\textbf{Chroma} = \sqrt{a^2 + b^2}$

Eq. (10) $\textbf{Hue angle} = \tan^{-1}\frac{b}{a}$

Eq. (11) $\textbf{TCD} = \sqrt{(L_0 - L)^2 + (a_0 - a)^2 + (b_0 - b)^2}$

2.5.11 Glass transition temperature

Differential scanning calorimeter (400-Ci Sanaf, Iran) was used to measure the glass transition temperature. The device was calibrated by indium in an aluminum pan. After calibration, 15 mg of the sample was poured into a sample pan. An empty aluminum pan was used as a reference. Nitrogen gas at constant flow of 30 ml / min was used. The glass transition temperature was in the temperature range of 20 to 200° C with a heating rate of 10° C / min. Finally, the obtained thermogram was used to measure the glass transition temperature [16].

2.5.12 FTIR

In this method, infrared radiation was used to determine the chemical properties of each sample. When an infrared beam strikes a sample, each of the chemical bond states (expansion, contraction, and bending) causes infrared light to be absorbed at a given wavelength. From the FTIR spectrum, various types of chemical and physical bonds and interactions between compounds can be investigated and identified. The FTIR spectrum were collected using an FTIR spectrometer (Cary 630, Agilent Technologies Incs., Danbury, CT, USA). For this test, about 2 mg of the sample was turned into a completely soft powder in an agate mortar and then about 10 mg of potassium bromide powder was added to it. This mixture was completely homogeneous and was formed into a very thin transparent tablet with the help of a special mold with a pressure of about 10

tons. The tablet was placed in the device compartment and scanned the range of 400 to 400 cm^{-1} and a resolution of 2 cm^{-1}[17].

2.6 Statistical analysis

In order to compare the mean of the samples with the control sample, a completely randomized design with one-way analysis of variance (ANOVA) in SPSS software was used. In order to reduce the error,all tests would be performed in 3 replications. The software used for the analysis was SPSS v.20. Excel 2007 was used to draw different figures from the mean of the data.

3. Results and discussion

3.1 Moisture

The results of moisture content of produced samples are shown in Figure (1). The results showed that different heat levels had a significant effect on moisture ($P \leq 0.01$). By increasing the microwave voltage and oven temperature which generate the higher heat and increase temperature, the speed of heat transfer to the particles during drying time increases and the final particles lose more moisture. Therefore, moisture decreased with increasing temperature. Moisture content is an important factor in the stability of the final powder. The optimum moisture range for powder samples is less than 5%. Less moisture reduces the adhesion of the powder and provides more surface contact with water during dissolution. If the moisture content of food powders is high, the possibility of undesirable physical changes increases, resulting in an increase in density and a decrease in flowability and solubility of the powders.

Kolawol et al. (2010) and Kadam and Blasubramanian (2011) reported similar results on banana and tomato powder, respectively [19, 20].

3.2 Water activity

223 The activity of water or the amount of water available is equal to the ratio of the water vapor
224 pressure in the food to the saturated vapor pressure at the same temperature. Due to the fact
225 that water is one of the most important causes of microbial, enzymatic and chemical spoilage
226 in food, reducing and controlling water activities is a very effective way to increase shelf life
227 and prevent adverse reactions in food. The presence of a porous structure in the foam and the
228 outflow of most of the free water during the drying process and the presence of gum with high
229 hydrophilicity is one of the main reasons for the low amount of water activity in beverage
230 powders. Since most of the microbial, chemical and enzymatic reactions stop in the water
231 activity of less than 0.6, it can be said that the powder prepared by foam mat drying, if properly
232 maintained and does not absorb moisture, would have a long shelf life. According to Figure
233 (2), the freeze-dried sample shows lower water activity due to its more porous structure.
234 Krasaekoopt et al. 2012 achieved different results in their research on the production of yogurt
235 powder using foam mat drying [23]. The water activity of the powders in this study was less
236 than 0.22. Therefore, powders can be considered microbiologically stable during storage.

237 **3.3 Solubility**

238 Water reabsorption involves several processes that occur simultaneously. These processes
239 include the infiltration of water into solid particles, the transfer of liquid from cavities to the
240 solid matrix, the swelling of solid particles, and finally the dispersion of particles into the
241 liquid. Water reabsorption is an important process for powders, as most powders dissolve in
242 water or an aqueous system before use. Optimal properties in reabsorption of the powder lead
243 to faster wetting and spreading of the powder. Poor reabsorption of the powder for
244 manufacturers leads to increased processing time, production costs and low product quality.
245 According to Figure (3), the effect of drying temperature on the solubility of beverage powder
246 showed that the drying temperature was significantly ($P \leq 0.01$) effective on the solubility of
247 the resulting powders. The increase in temperature increased the condition of the beverage

248 powder samples. At 900 voltage of microwave, the solubility decreased with increasing drying
249 temperature due to changes in the hydrophilic structure of carbohydrates or denaturation of the
250 protein. The freeze-dried sample showed more solubility compared to other samples.

251 According to the research of Affandi et al. (2017) on foam mat drying of Fennel flower; it was
252 found that with increasing temperature, the solubility of the powder also increased. They
253 attributed this to the increase in temperature-induced porosity. More porosity causes more
254 surface area in the powders, which leads to an increase in the surface contact between the
255 powder and water [9, 24]. Increasing the temperature reduces the interparticle forces of the
256 powder and the degree of the

257 powder cohesion. As cohesion decreases, the space between the powder particles increases.
258 This causes faster and more water absorption [25]. Increasing the temperature helps to better
259 preserve the bubbles until the end of drying and thus increases the porosity and solubility [26].

260 **3.4 water binding capacity**

261 Absorption of water is one of the most important properties of the powder and indicates the
262 ability of the powder to absorb and retain water against gravity and it depends on the chemical
263 composition of the powder such as protein, moisture and carbohydrates, its physical state such
264 as particle shape and size, surface properties, microstructure and the presence of additives [27].
265 Gums, due to their hydrophilic nature, are important factors in water absorption in beverage
266 powder prepared by foam mat method. Figure (4) shows the water binding capacity of beverage
267 powder samples. The results showed that the drying temperature had a significant effect ($P \leq$
268 0.01) on the water binding capacity of the resulting powders. Increasing the drying temperature
269 first increases the water absorption capacity of the prepared powder and then, due to the
270 denaturation of proteins and the placement of hydrophobic groups on the protein surface, the
271 water absorption capacity decreases at high drying temperatures.

3.5 Rehydrating the powder

Wettability is a measure of the infiltration of water through the capillary forces into the powder mass. Wettability is often considered to be equal to the time required for complete wetting of the surface of the powder particles [28]. In addition, increasing the temperature leads to changes in water properties such as viscosity and surface tension of water. Reduction of surface tension of water leads to a decrease in the cohesion between water molecules and as a result water penetrates faster on the surface of powder particles. The results of the evaluation of the rehydration of the produced powder samples are given in Figure (5). The results showed that different levels of heat had a significant effect ($P \leq 0.01$) on the rate of rehydration of the powder. At high drying temperatures, a decreasing trend was observed, which could be due to damage to the structure of carbohydrates and proteins. Freeze-drying method resulted in the production of more porous powders. Rehydration is important in most food powders, which means that the powders should be able to get wet in the shortest amount of time and stay less floating. In addition, powders should be able to be easily dissolved or dispersed in water without the formation of lumps [29].

3.6 Hygroscopy

Hygroscopy shows the ability to absorb water at high relative moisture. Increasing the temperature led to the production of a powder with the ability to absorb more moisture. The lower the moisture content of the product, the higher the tendency to absorb the moisture [30]. Figure (6) shows the hygroscopic extent of beverage powder samples. Studies showed that drying temperature has a significant ($P \leq 0.01$) effect on moisture absorption in the resulting powders.

Moisture absorption capacity or hygroscopicity of freeze-dried powders depends on their particle size. The smaller the particle size, the larger the surface area exposed to the

environment, thus leading to more water absorption. Products with smaller particles have a higher contact surface and therefore the number of active sites for water absorption increases [31]. Freeze-dried powder had more porous structure and open pores than other samples.

3.7 Powder flowability

The flowability usually depends on the physical properties of the powder such as size, shape, surface structure, particle density, bulk density, moisture content, temperature, pressure and fat. The flowability of the powder is measured by the Carr index (CI) and this index is inversely related to the flowability, so that as the powder Carr index increases, the flowability of the powder becomes weaker. Powder cohesion can be calculated by the Hausner ratio (HR), which is a measure of the state transfer from free flow to adhesion of powders. By monitoring this factor, it is possible to predict relatively stable operating and processing points in terms of particle size and relative moisture. The values of the Carr index and the Hausner ratio of beverage powders are shown in Figure (7). Different heat levels had a significant effect on powder flowability rate ($P \leq 0.01$).

The adhesion between the particles due to its high sugar content is also affected by the glass transition of amorphous sugars. By dissolving the powder in water and preparing the beverage, water molecules moisten the surface of the particles, reducing the intrinsic binding of the particles and allowing water to penetrate more rapidly throughout the food. Powders with higher setting angles are unlikely to sink easily due to their intrinsic binding after pouring into the liquid surface.

The density and porosity of the powder, which is affected by the amount of air and free space between the particles, has a positive correlation with the wetting time, which decreases as

particle size increases. Increasing the particle size not only increases the rate of water penetration into the interparticle space of the powders, but also creates a flow of water capillary system inside the powder space, which mainly reduces the wetting time of the powder. As the contact surfaces increase and the particle size decreases, the wetting time of the powders decreases significantly. Bulk density is a measure of the compaction properties of particulate solids, and this measure indicates the amount of empty space between the powder particles, so it depends on the particle density and the arrangement of particles in the powder bed.

During freeze-drying, the texture is well preserved, while in drying in hot air, the sample shrinks significantly. Hence the density of the samples is much lower than drying in hot air. Smaller particles can easily enter the space between the particles while tapping. Tapped densities were higher in hot air dried powders than in freeze-dried powders [18].

3.8 Porosity

Bulk density decreased with increasing temperature. In general, with increasing temperature due to the formation of more resistant crust around the particles, the porosity created is more stable and as a result the bulk density decreases. As the moisture in the produced powder increases, the amount of trapped air decreases and as a result the bulk density will increase [22].

Bulk density is a measure of the compaction properties of particulate solids. In some granular foods, an increase in bulk density is associated with an increase in moisture content, and some researchers have reported a negative linear relationship. The effect of moisture content on the

bulk density of particulate food can be very different and depends on the nature of the constituent particles and their interaction [23]. Figure (9).

3.9 pH

As shown in Figure (10), the pH range of beverage powders is 4 to 4.25. Due to the presence of egg white powder and gum and higher pH of these compounds, the pH of the beverage powder showed higher values than the pH range of the orange beverage. According to previous research, it has been shown that with increasing temperature, an increasing range is observed in pH values. Flade et al. 2010 reported similar results on banana powder [31].

3.10 Colorimetry

Color is one of the first and most important physical properties of the powder, which directly reflects the conditions applied during the drying process and the quality of the final product. The results of color component evaluation (L^* a^* b^*) are shown in Table (1). As the results show, different microwave voltages and different oven temperatures had a significant effect of 1% on the amount of color components of the product and its color intensity. So that the highest amount of color component was related to the sample dried with freeze-dryer, while the lowest amount was observed in the dried sample with a voltage of 900 microwaves. Reduction of this color component means darkening of the samples, which was directly related to the increase in product microwave voltage and oven temperature. The type of dryer and increasing the temperature of the dryer can also be very effective and can reduce the quality of the final product. On the other hand, the findings showed that the highest amount of component L^* was allocated to the sample sample dried with freeze-dryer. Also, the highest amount of color component b* was in the sample with a voltage of 900 microwaves. Hawlader et al. (2006) stated that the low value of the Hue color index indicates an increase in the amount of brown color due to browning reactions [30].

3.11 Glass transition temperature

Glass transfer temperature is the main indicator of amorphous phase temperature changes of materials. It is the temperature at which materials change phase from brittle and glassy to rubbery and viscous. Therefore, with increasing the glass transition temperature, the adhesion of the powder decreases [28]. In general, low glass transition temperatures cause problems such as sticking to the wall, reducing production efficiency and increasing operational problems. The thermophysical properties of food and beverages such as specific heat, glass transition temperature, etc. are very important for estimating the process time in cooling, freezing, heating and drying of food and beverages.

Powders are very sensitive to the temperatures and moisture of the storage environment and their structure can change from glass to rubber, which causes changes in the glass transition temperature. Also, higher moisture content reduces the glass transition temperature and produces a powder with high viscosity. Preserving dried foods above their glass transition temperature, due to the increased internal movement of the reactants, leads to increased changes and various chemical reactions in them, and as a result, they will have less stability and shelf life. It should be noted that moisture, temperature and components of the product to be dried have a very important role on the glass transition temperature. The glass transition temperature of water is very low (-135 degrees) and the presence of a small amount of it is sufficient to drastically reduce the glass transition temperature of the powder produced [29].

Figure (11) shows the glass transition values of beverage powder under different drying conditions. This shows the stability of the powder during production. higher glass transition temperature results in the higher resistance of the powder.

The low glass transition temperature in the beverage foam is due to the presence of sugar in the sample. These sugars have a low glass transition temperature and due to the low molecular weight of the components, they show high molecular mobility when the temperature is slightly

388 higher than the glass transition temperature [33]. Destructive reactions can be prevented by
389 keeping the product at a temperature lower than the glass transition temperature and proper
390 capping to prevent moisture exchange with the environment.

391 **3.12 FTIR**

392 The results of FTIR analysis of beverage powder samples are shown in Figure (12). Significant
393 differences were observed in the regions between 800 -1650 and 2900-3300 which can be
394 attributed to intermolecular interactions between protein and polysaccharide. Peaks below
395 1200 have been attributed to gum, according to Ma and Pawlik (2007). The peaks obtained in
396 900-1200 are attributed to c-o and c-o-c bonds and also the adsorption in 1229-1301 is
397 attributed to C-N and N-H bonds. The peak 2800-3000 is related to the C-H bond in the methyl
398 group. The peak at point 3300 refers to the o-H bond in the water molecule [16, 35].

399 **Conclusion**

400 In this study, the effect of different drying condition of foam mat drying method on some
401 physicochemical properties of orange beverage powder was investigated. Due to the porous
402 structure of the foam, the rate of mass and heat transfer during the drying process in the foam
403 mat drying method is increased. Also, the possibility of drying the food at a lower temperature
404 and shorter drying time causes the porous structure of the dried foam sample to absorb water
405 faster and increases the dissolution rate of the product. Freeze dried beverage powder had the
406 maximum solubility and highest flowability and it was evaluated as a desirable sample. Due to
407 the efficiency of this method in drying food with high concentration and producing a product
408 with suitable physical and chemical properties and low energy consumption, this method can
409 be used for industrial production of food powders.

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413

414 **CONFILICT OF INTEREST**

415 The authors declare no conflict of interest.

416 **ETHICAL APPROVAL**

417 The human and animal testing was unnecessary in the current study.

418 **DATA AVAILABILITY STATEMENT**

419 The authors declare that data supporting the findings of this study are available within the
420 article.

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List of table captions

Table 1. Effect of drying condition on color values of foam mat dried orange beverage powder.

Figure Legends

Figure 1. Effect of drying condition on moisture of foam mat dried orange beverage powder. (OD). Oven with (45, 65 and 80) temperatures, (MW).Microwave with (360, 600 and 900) power, (FD).Freeze-dryer.

Figure 2. Effect of drying condition on water activity of foam mat dried orange beverge powder. (OD). Oven with (45, 65 and 80) temperatures, (MW).Microwave with (360, 600 and 900) power, (FD).Freeze-dryer.

Figure 3. Effect of drying condition on solubility of foam mat dried orange beverage powder. (OD). Oven with (45, 65 and 80) temperatures, (MW).Microwave with (360, 600 and 900) power, (FD).Freeze-dryer.

Figure 4. Effect of drying condition on water binding capacity of foam mat dried orange beverage powder. (OD). Oven with (45, 65 and 80) temperatures, (MW).Microwave with (360, 600 and 900) power, (FD).Freeze-dryer.

Figure 5. Effect of drying condition on rehydration of foam mat dried orange beverage powder. (OD). Oven with (45, 65 and 80) temperatures, (MW).Microwave with (360, 600 and 900) power, (FD).Freeze-dryer.

Figure 6. Effect of drying condition on hygroscopicity of foam mat dried orange beverage powder. (OD). Oven with (45, 65 and 80) temperatures, (MW).Microwave with (360, 600 and 900) power, (FD).Freeze-dryer.

550 **Figure 7**. Effect of drying condition on carr index of foam mat dried orange beverage powder.
551 (OD). Oven with (45, 65 and 80) temperatures, (MW).Microwave with (360, 600 and 900)
552 power, (FD).Freeze-dryer.

553

554 **Figure 8**. Effect of drying condition on haunser ratio of foam mat dried orange beverage
555 powder. (OD). Oven with (45, 65 and 80) temperatures, (MW).Microwave with (360, 600 and
556 900) power, (FD).Freeze-dryer.

557

558 **Figure 9**. Effect of drying condition on porosity of foam mat dried orange beverage powder.
559 (OD). Oven with (45, 65 and 80) temperatures, (MW).Microwave with (360, 600 and 900)
560 power, (FD).Freeze-dryer.

561

562 **Figure 10**. Effect of drying condition on pH of foam mat dried orange beverage powder. (OD).
563 Oven with (45, 65 and 80) temperatures, (MW).Microwave with (360, 600 and 900) power,
564 (FD).Freeze-dryer.

565

566 **Figure 11**. Effect of drying condition on the DSC thermogram of orange beverage powder.
567 (OD). Oven with (45, 65 and 80) temperatures, (MW).Microwave with (360, 600 and 900)
568 power, (FD).Freeze-dryer.

569

570 **Figure 12**. FTIR spectra of orange beverage powder at different drying temperature. (OD).
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572 (FD).Freeze-dryer.

573

574

575

576 **Table 1**. Effect of drying condition on color values of foam mat dried orange beverage
577 powder.

Treatment	L	a	b	TCD	chroma	$tan^{-1}b/a$
OD45	83.42± 9.9^{ab}	-6.6± 0.4^{c}	74.19±2.9^{bc}	117.23±0.11^{a}	71.04±0.03^{e}	84.91±0.01^{e}
OD60	84.74±7.8^{ab}	-2.27±0.5^{bc}	74.49±1.4^{bc}	116.74±0.24^{b}	75.34±0.3^{c}	88.25±0.02^{a}
OD80	75.4±8.02^{b}	6.84± 6.1^{a}	71.31±5^{c}	113.78±0.24^{c}	76.09±0.08^{b}	84.52±0.002^{f}
MW360	81.66±81.66^{ab}	4.44±0.08^{a}	70.33±0.26^{c}	107.76±0.14^{f}	70.57±0.06^{f}	86.38±0.003^{d}
MW600	83.10±83.10^{ab}	3.76±0.4^{ab}	76.04±1.1^{ab}	112.38±0.06^{d}	74.56±0.4^{d}	87.16±0.001^{c}
MW900	81.70±81.70^{ab}	3.33±0.23^{ab}	79.18±0.7^{a}	113.95±0.04^{c}	79.13±0.11^{a}	87.59±0.002^{b}
FD	89.36±89.36^{a}	-7.46±0.06^{c}	62.2±0.05^{d}	109.11±0.09^{e}	62.42±0.35^{g}	83.16±0.002^{g}

578

Figures

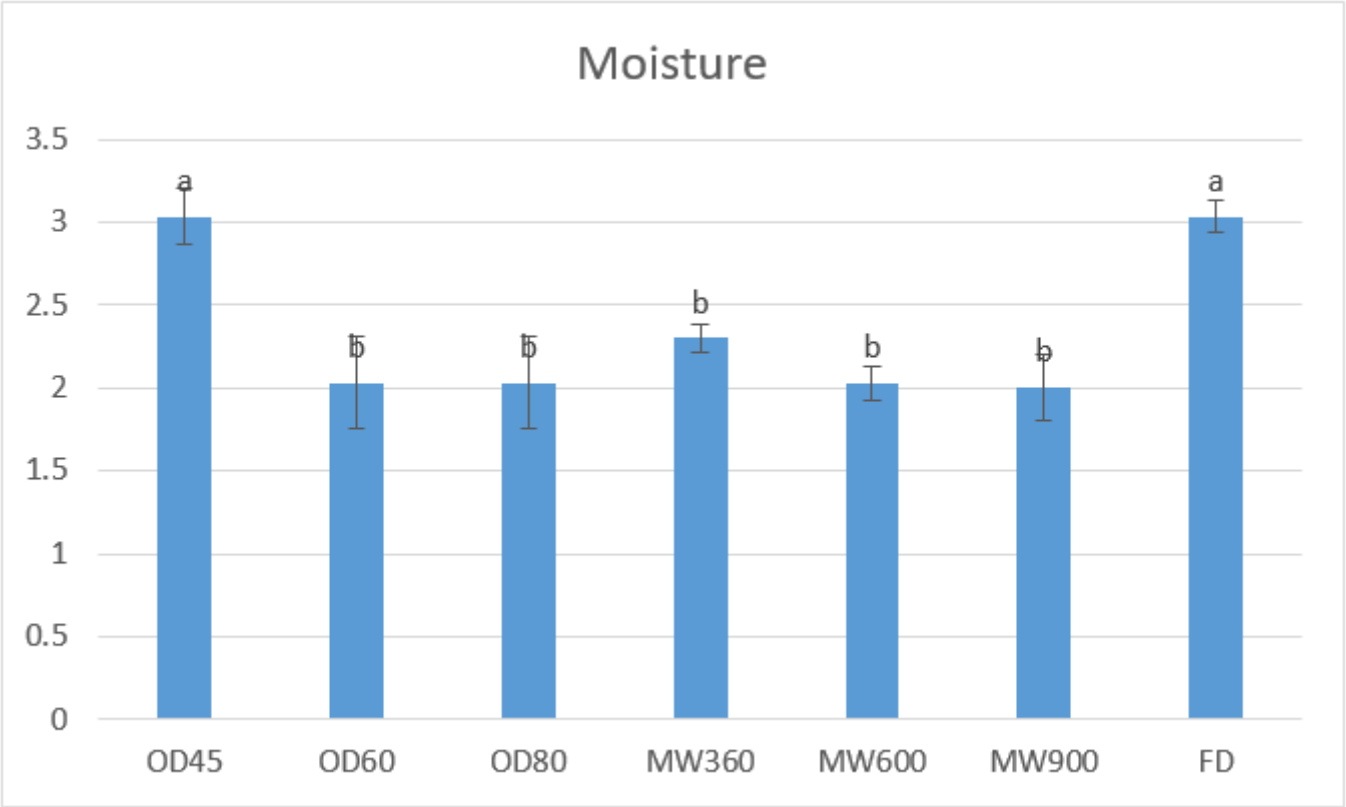

Figure 1

Effect of drying condition on moisture of foam mat dried orange beverage powder.

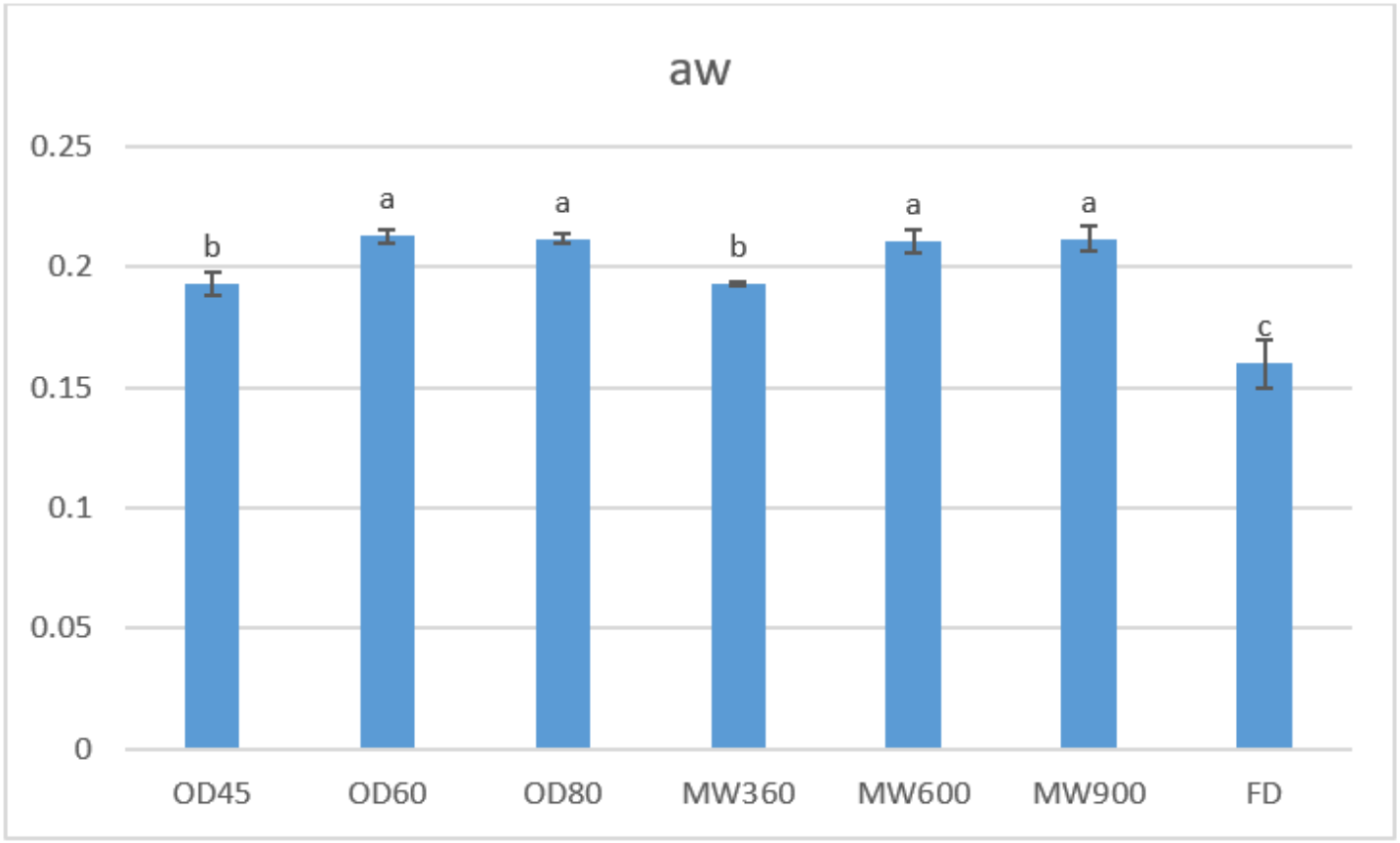

Figure 2

Effect of drying condition on water activity of foam mat dried orange beverge powder.

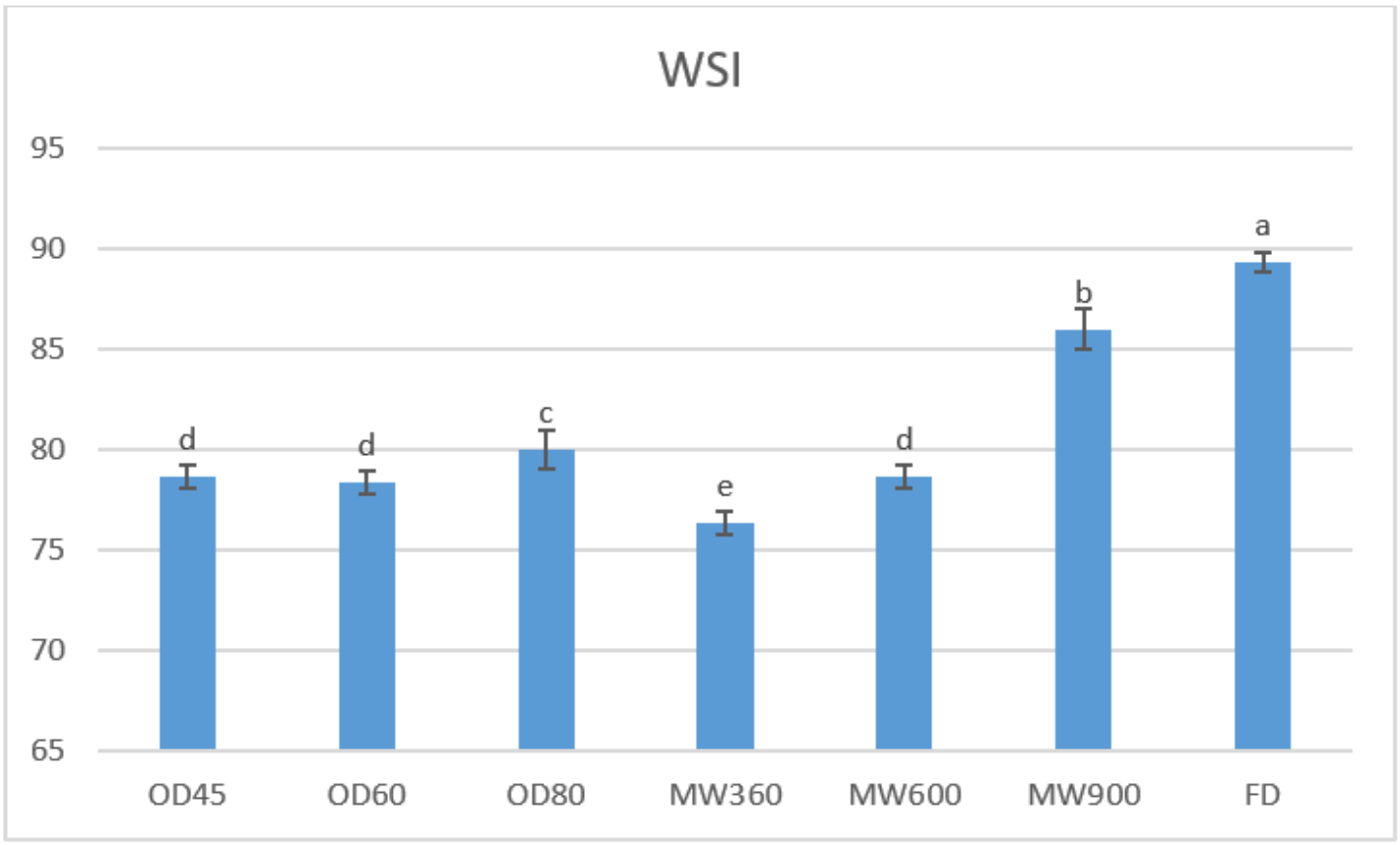

Figure 3

Effect of drying condition on solubility of foam mat dried orange beverage powder.

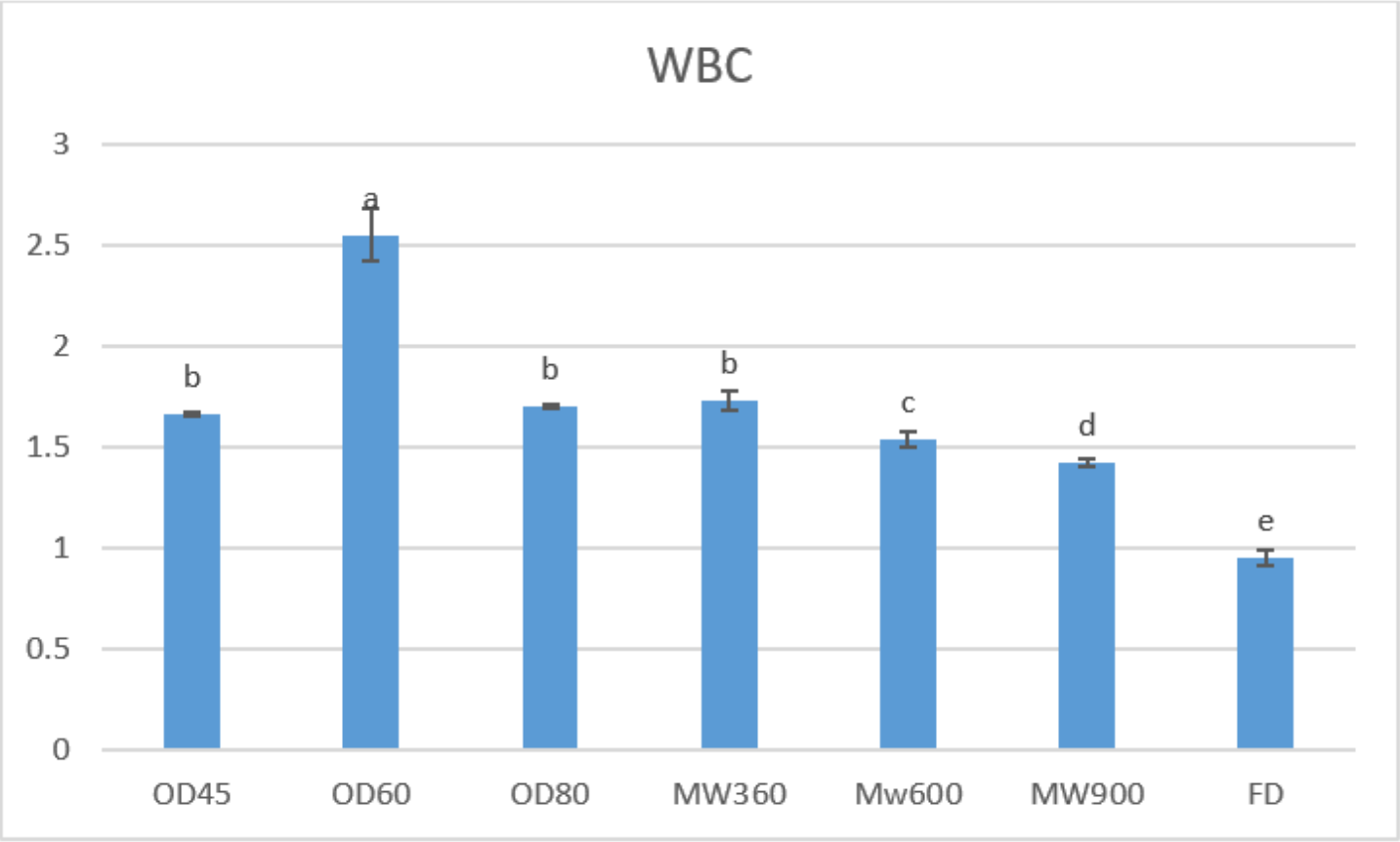

Figure 4

Effect of drying condition on water binding capacity of foam mat dried orange beverage powder.

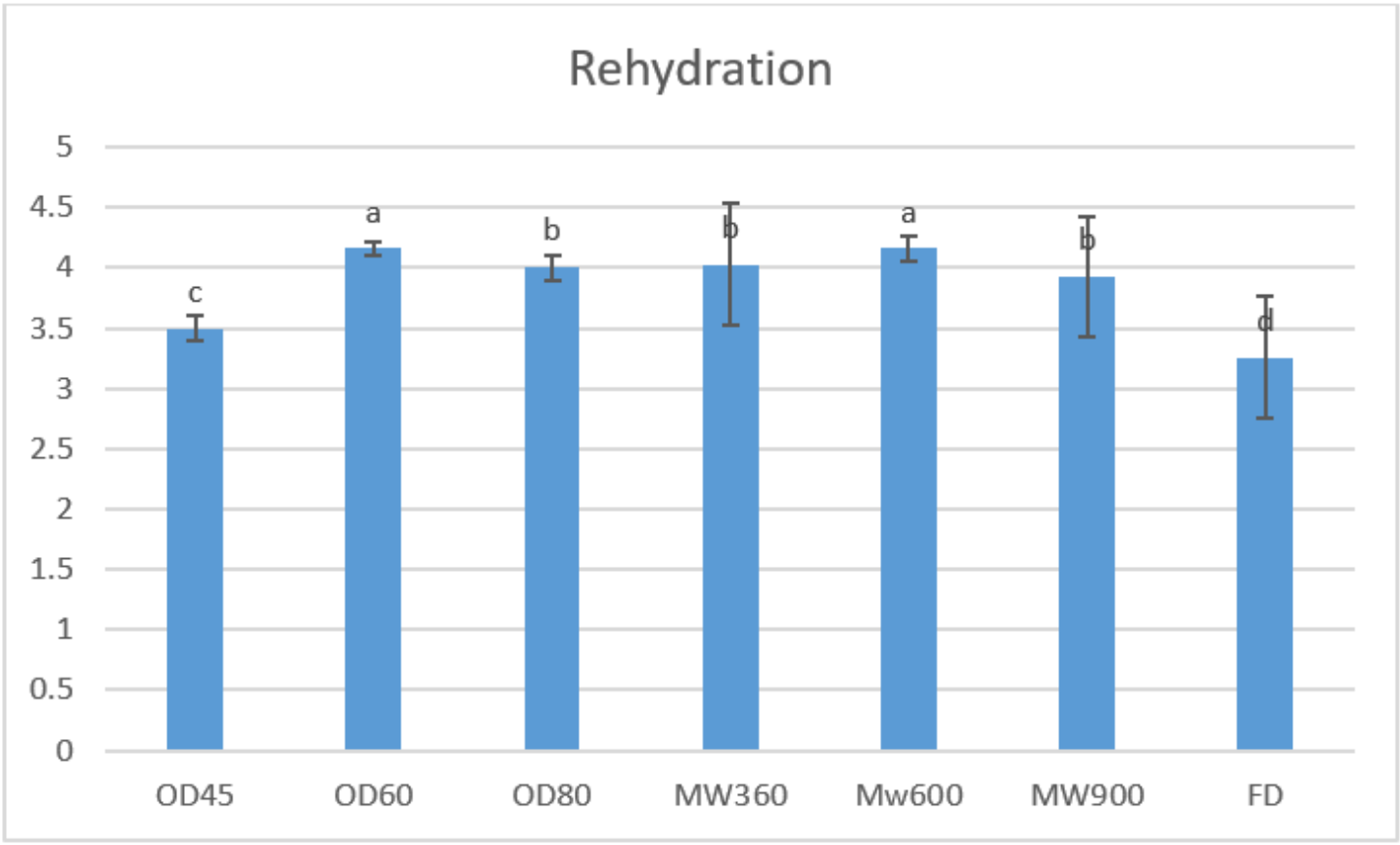

Figure 5

Effect of drying condition on rehydration of foam mat dried orange beverage powder.

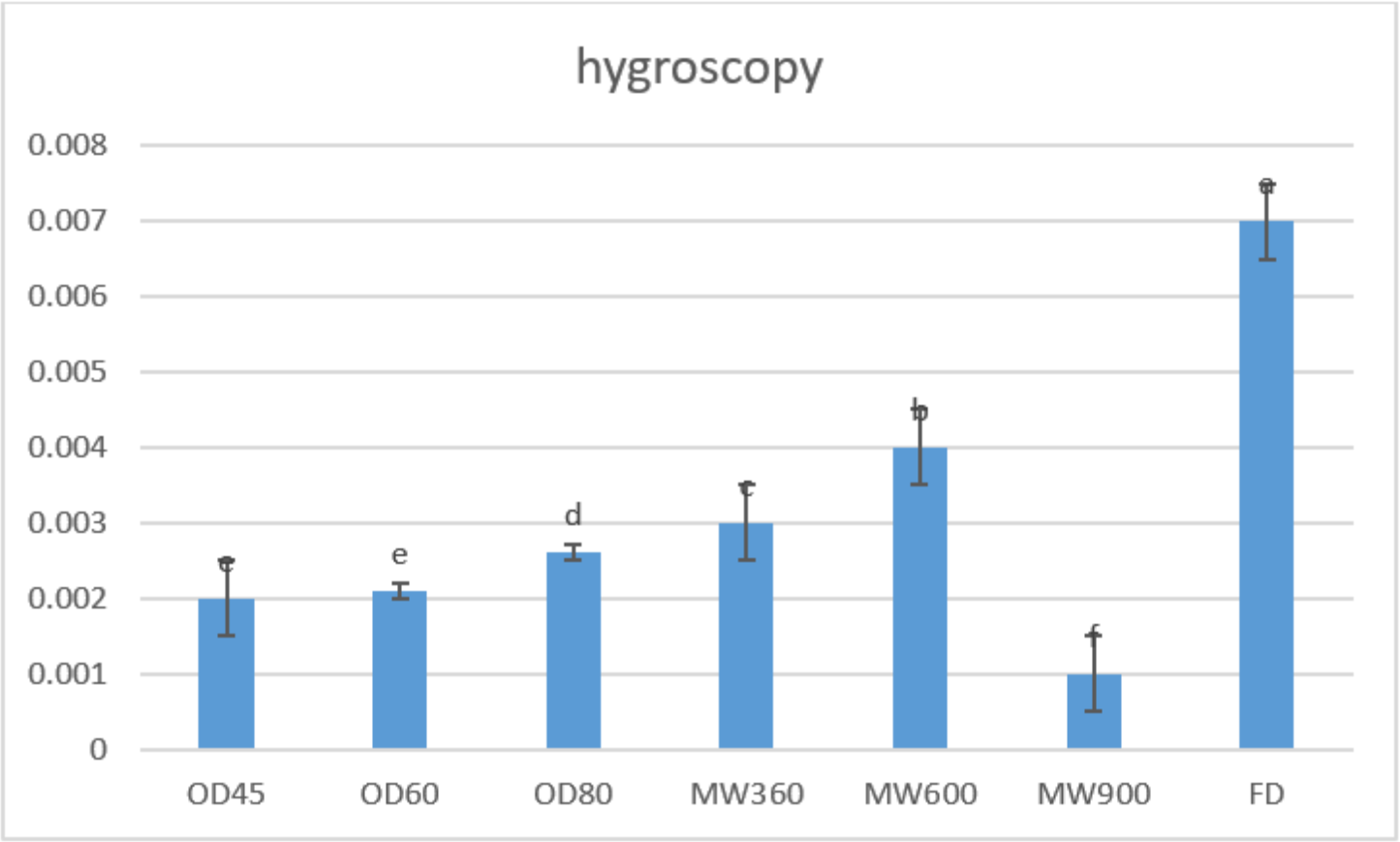

Figure 6

Effect of drying condition on hygroscopicity of foam mat dried orange beverage powder.

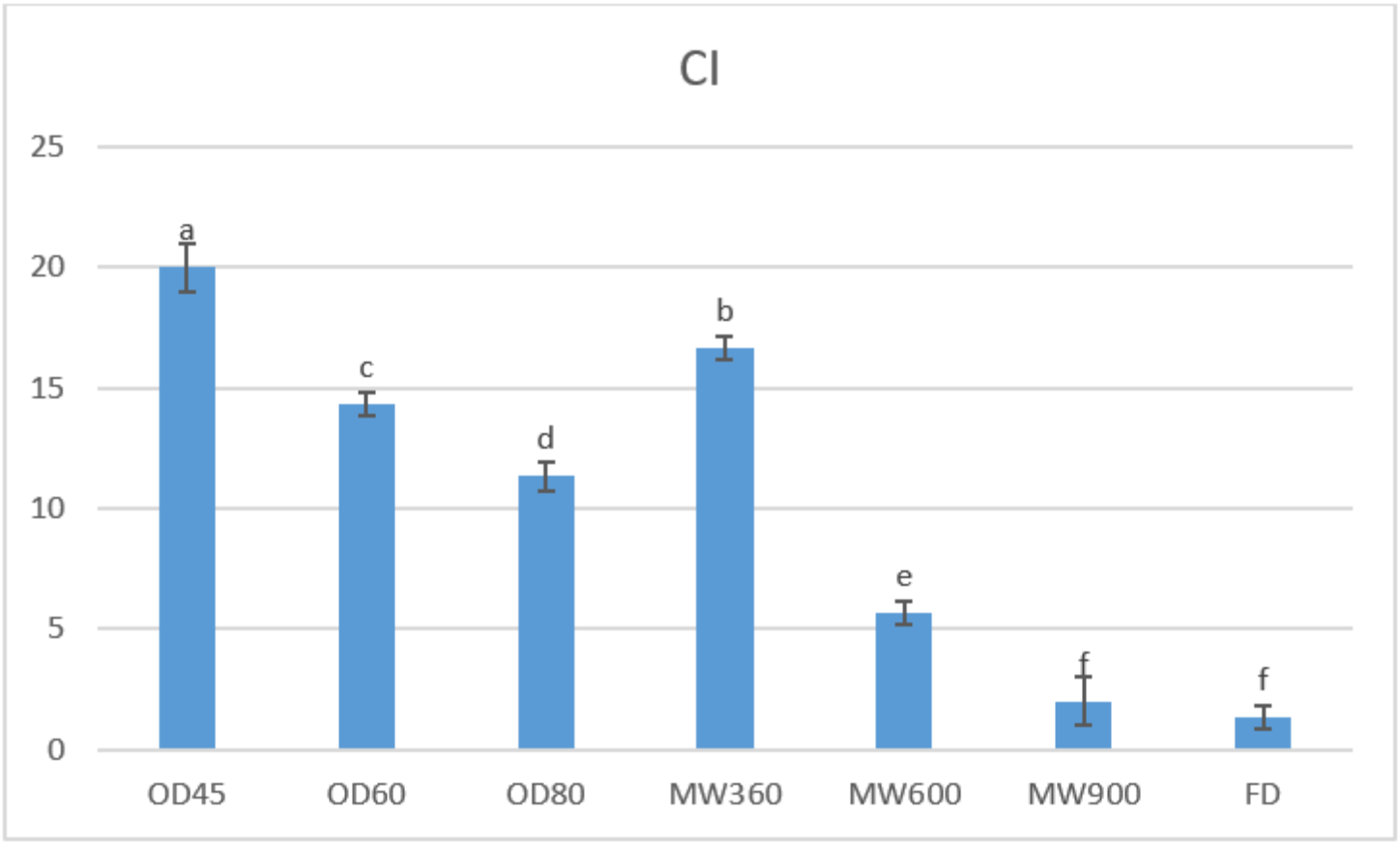

Figure 7

Effect of drying condition on carr index of foam mat dried orange beverage powder.

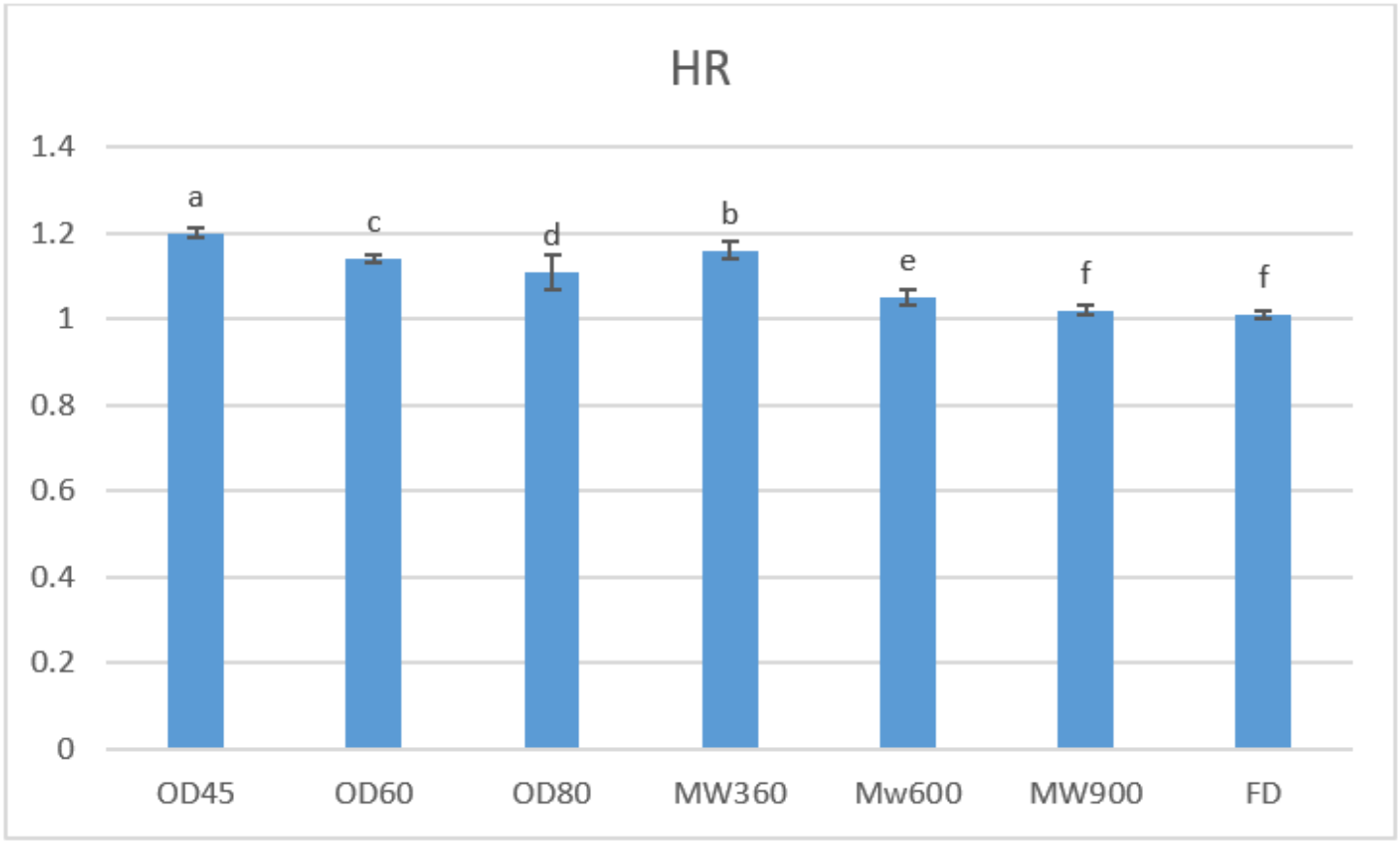

Figure 8

Effect of drying condition on haunser ratio of foam mat dried orange beverage powder.

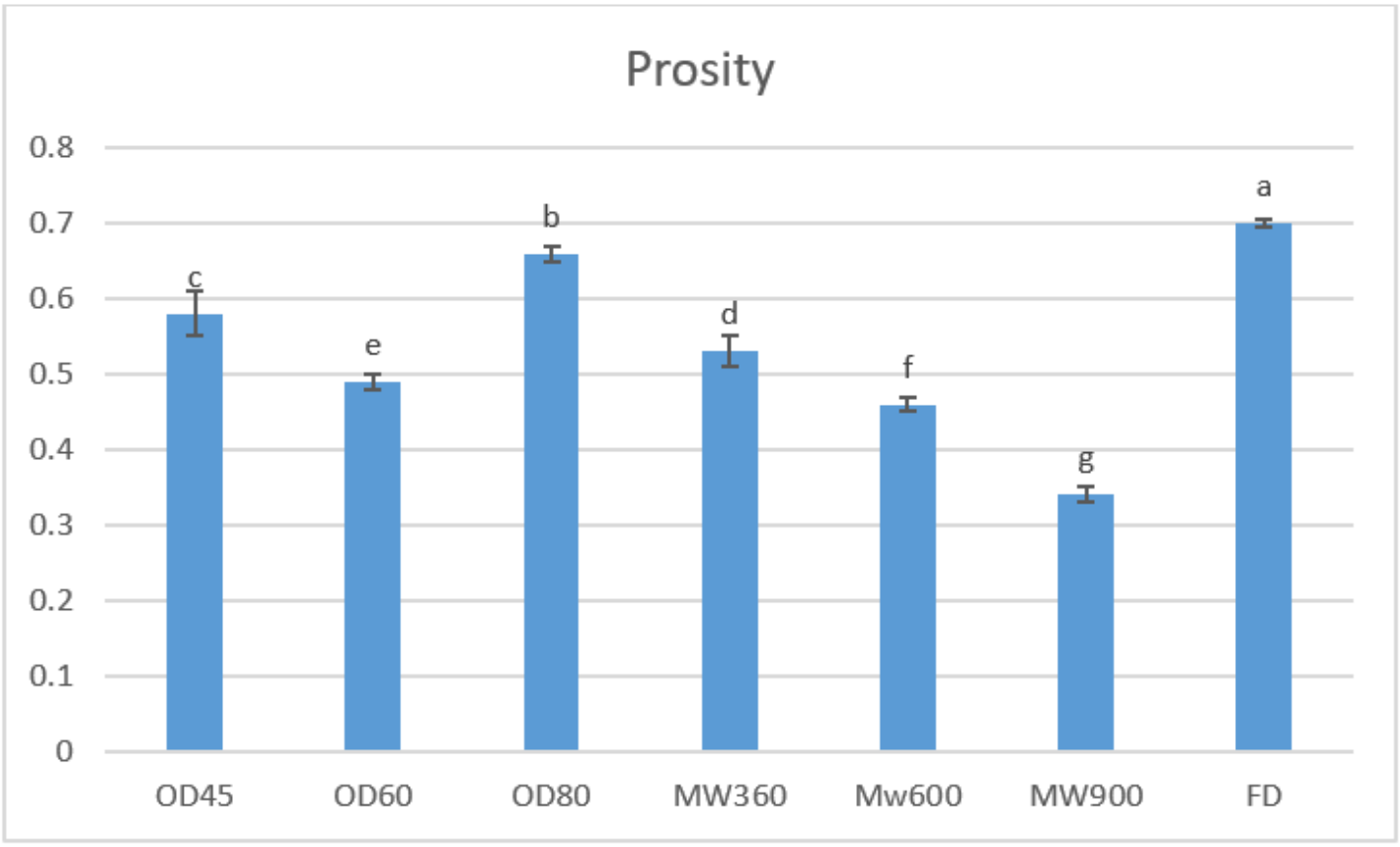

Figure 9

Effect of drying condition on porosity of foam mat dried orange beverage powder.

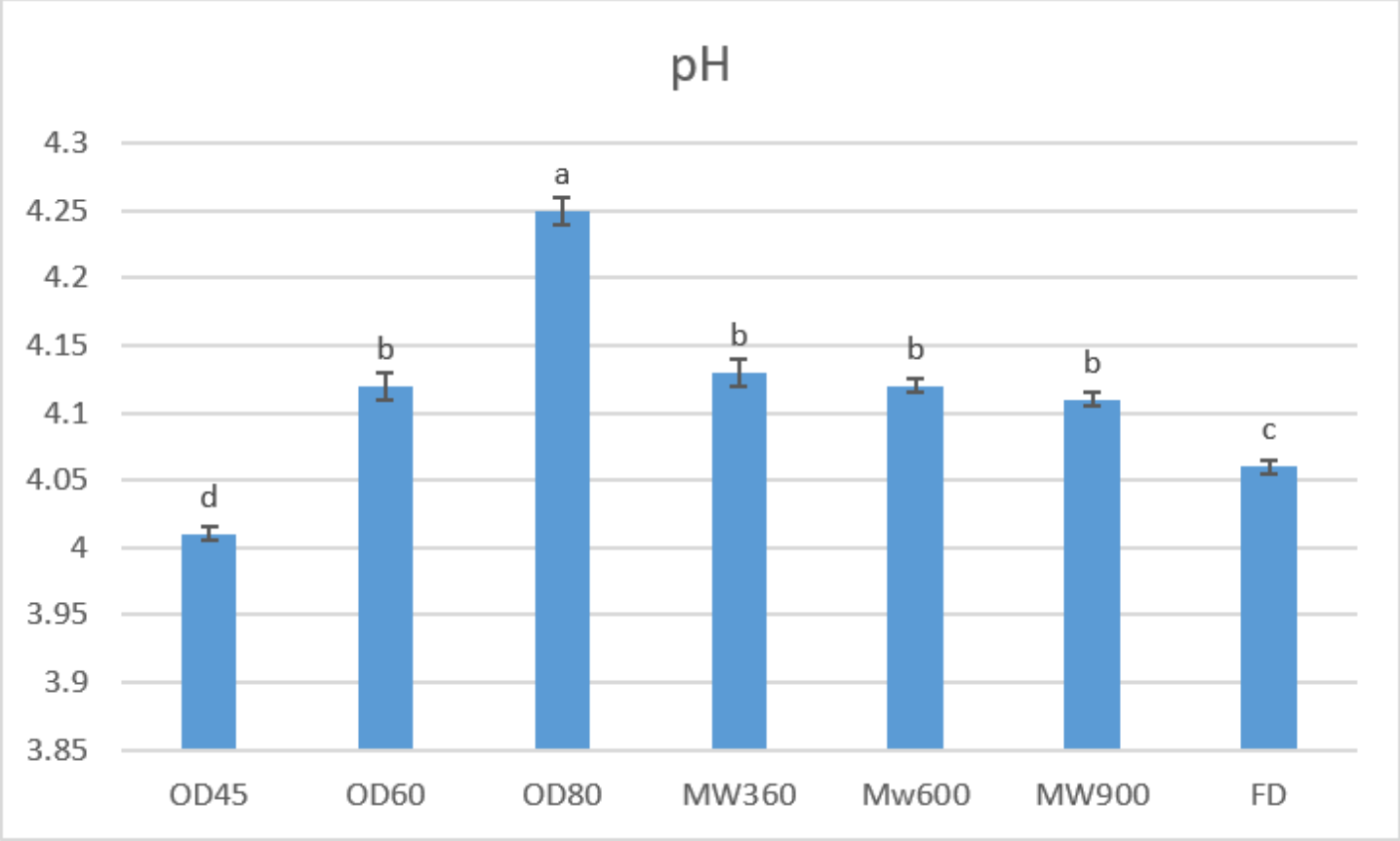

Figure 10

Effect of drying condition on pH of foam mat dried orange beverage powder.

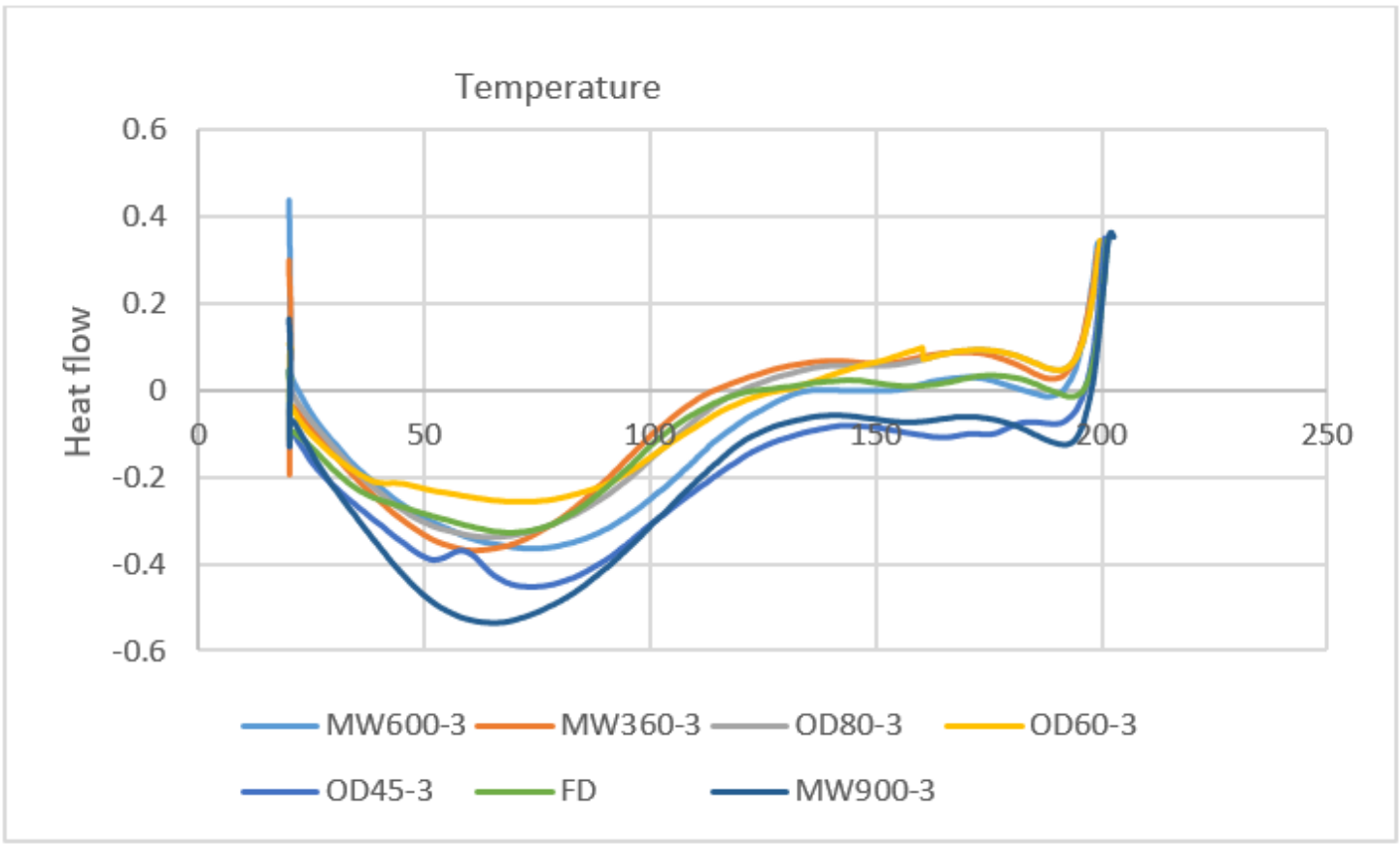

Figure 11

Effect of drying condition on the DSC thermogram of orange beverage powder.

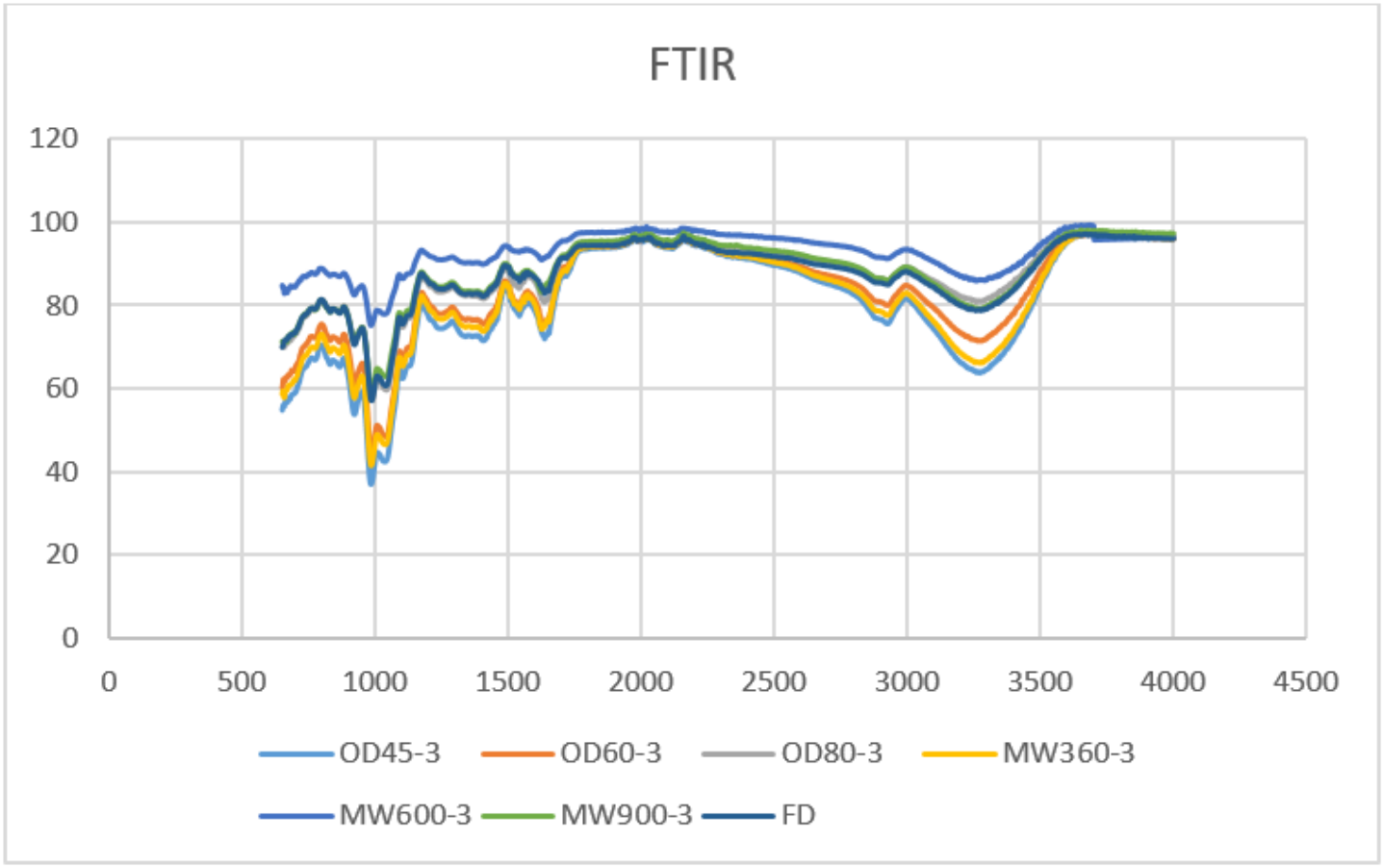

Figure 12

FTIR spectra of orange beverage powder at different drying temperature