Journal of Food Science and Technology (Iran)

Homepage:www.fsct.modares.ir

Scientific Research

Foam mat drying of orange juice using cress seed gum and egg albumin

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ARTICLE INFO

Article History:
Received:2023/10/28
Accepted: 2024/1/6

Keywords:

Orange juice,
Cress seed gum,
Foam mat drying,
Protein,
Powder properties

DOI: **10.22034/FSCT.21.147.131.**

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ABSTRACT

In this research, cress seed gum in three concentrations (0.1, 0.2 and 0.3%) as a stabilizer and egg white powder in four levels (1, 2, 3 and 4%) was used to produce orange juice foam and then the optimal foam sample (minimum density, maximum stability and overrun) was selected. Next, the optimal sample for drying by foam mat drying method was dried at three different temperatures (40, 55 and 70 C) by hot air dryer. The results showed that by decreasing the concentration of cress seed gum and increasing the concentration of egg white protein, the overrun increased significantly and the density decreased ($p<0.05$). Also, by increasing the concentration of cress seed gum and egg white protein, the stability of the foam improved. Among all the treatments, the sample containing 4% egg white powder and 0.1% cress seed gum, in addition to low drainage (drainage volume 0.5 ml), has low density (0.321 gr/cm) and high overrun (308 percent) which was selected as the best treatment for the production of orange powder. The drying time of orange pulp at temperatures of 40, 55 and 70 degrees Celsius was 100, 150 and 280 minutes, respectively. The effective diffusion coefficient in the temperature range of 40 to 70 degrees Celsius was in the range of 1.38 x 10-7 to 2.938 x 10-7 m2/s. The results showed that by increasing the temperature from 40 to 70 degrees Celsius, the solubility of the powder increased, while the water activity of the powder, density and reabsorption of water decreased significantly ($p<0.05$). Also, the results of color analysis showed that with increasing drying temperature, color indices (L*) and (a*) increased significantly and color index (b*) decreased

1. Introduction

Citrus sinensis, commonly referred to as the orange, is the second most consumed fruit globally. Its cultivation originated in the northeastern regions of India and central China, but it is now grown and harvested in various parts of the world. This species, a member of the Rosaceae family, is classified as an evergreen plant [1]. Orange juice, one of the most favored fruit juices, accounts for approximately half of the world's fruit juice production with an annual yield of about 63 million tons. The high commercial value of orange juice can be attributed to its appealing sensory properties, rich vitamin C content, and abundance of natural antioxidants. A significant challenge in the commercialization and distribution of orange juice is its limited shelf life [2]. The primary factors contributing to quality degradation during the product's shelf life include loss of flavor, microbial spoilage, and ascorbic acid degradation. Consequently, researchers are exploring various methods to extend the shelf life of this product [3-4].

Foam mat drying is an emerging, cost-effective technique for dehydrating liquid, semi-liquid, and concentrates, which has garnered considerable attention from researchers [5]. In this method, foaming and stabilizing agents are added to the liquid food using foam generation techniques (mixing, shaking, or gas injection), resulting in a stable foam with a porous structure. This foam is then dried from the bottom up using hot air. The increased contact surface and high rate of moisture transfer from the foam mat enable the food to be dried at a lower temperature and in a shorter time span, thereby preserving the quality of the food and minimizing thermal damage [6]. Furthermore, due to their porous structure, the products manufactured using the foam mat drying method can be rapidly rehydrated, even in cold water [7].

Food substances with a low protein content struggle to generate stable foams when stirred, necessitating the use of foam-generating and foam-stabilizing agents in the foam mat drying process. Surface-active compounds, possessing both hydrophilic and hydrophobic components, increase surface tension and enhance foam stability when positioned at the interface of dispersed and continuous phases [8]. Molecular structures of proteins composed of amino acids containing hydrophobic and hydrophilic parts. The structure of such compounds facilitate foam creation in the food industry. Egg white powder is one of the most crucial proteins utilized in the food industry due to its numerous functional properties such as foaming properties, water retention, gel formation, and high emulsifying properties. The main proteins of egg white are ovalbumin, ovotransferrin, ovomucoid, and lysozyme. Ovalbumin constitutes approximately 54% of egg white proteins. The molecular weight of ovalbumin is approximately 45 kDa, it has an isoelectric pH of about 4.5, and a denaturation temperature range of 71.5-84 °C [8-9].

Nowadays, a variety of stabilizers are employed in the food industry, the majority of which are natural polysaccharides possessing high molecular weights. Their hydrophilic properties, high molecular weights, and gelling behaviors contribute to an increase in the viscosity of the aqueous phase, leading to the formation of macromolecular barriers. This strengthens the bubble wall and ultimately enhances the stability of the foam [10]. *Lepidium sativum*, belonging to the *Ruciferae* family, is an annual herbaceous plant indigenous to South and Southwest Asia. The seeds of *Lepidium sativum*, characterized by their high water absorption capacity, produce a

high molecular weight mucilage. The composition of this gum, with a high mannose to galactose ratio (8:2), enables its use as a substitute for some hydrocolloids [11]. The seed shell, rich in polysaccharides, plays a crucial role in inducing viscosity and gel formation [12]. The gel derived from *Lepidium sativum* gum exhibits a fully uniform and resilient texture, capable of withstanding high temperatures. Moreover, heating induces an irreversible increase in the viscosity of its solutions, a feature that aids in maintaining the viscosity of the dough at elevated temperatures. The rheological behavior of the *Lepidium sativum* is similar to xanthan gum, so it can be considered as a novel gum that serves as a substitute for some commercial hydrocolloids. It also offers additional benefits due to its therapeutic properties and plant-based origin [13]. The objective of this research was to produce orange juice powder using foam mat drying method.

2-materials and methods

2.1. materials

Oranges, *Siavaraze* variety, and egg white powder, were obtained from local shops. Freeze-dried *Lepidium sativum* gum was obtained from the Central Laboratory of Mazandaran Science and Technology Park.

2.2. Preparing gum aqueous solution

To prepare gum aqueous solutions, determined gum powders were dissolved in deionized water. The mixture was stirred using a magnetic stirrer and subsequently refrigerated for 24 h to ensure complete hydration of the gum molecules [14].

2.3. foam preparation

The oranges manually washed, entirely peeled and subsequently juiced. The Brix of the orange juice was set utilizing a digital refractometer (a/kruess, DR 301-95, Germany). To produce foam, different concentrations of egg white powder (1, 2, 3, and 4%) serving as a foaming agent, and different levels of *Lepidium sativum* gum (0.1, 0.2, and 0.3%) to establish foam stability, was weighted in a container and fresh orange juice was then added until the total mass reached 100 g. The different concentrations of gum and egg white powder used in this study are delineated in Table 1.

Table 1 Different treatments of foam production

Code	A1B1	A1B2	A1B3	A2B1	A2B2	A2B3	A3B1	A3B2	A3B3	A4B1	A4B2	A4B3
Protein concentration	1	1	1	2	2	2	3	3	3	4	4	4
	0	0	0	0	0	0	0	0	0	0	0	0
Gum concentration	.1	.2	.3	.1	.2	.3	.1	.2	.3	.1	.2	.3

2.4. powder preparation

The most suitable foam (the highest overrun and stability, and the lowest density) was selected for the powder production. An air circulating oven (Memmert, Germany) was employed to dry foam. Foams were poured into aluminum containers with 4 mm thickness and the

influence of different drying temperatures (40, 55, and 70 °C) on the properties of the resultant powder was investigated. Prior to the further tests, the produced powders were sieved through a 40 mesh screen to standardize the particle size [7].

2.5. Foam properties

2.5.1. Foam density

A foam was freshly prepared at room temperature and was immediately transferred into a 50 ml graduated cylinder. The density of the foam was subsequently computed by dividing its weight by its volume [15].

)Eq. 1 (

$$\textbf{foam density} = \frac{\boldsymbol{foam\ weight\ (g)}}{\textbf{foam volume}\ (\boldsymbol{cm^3})}$$

2.5.1. Foam stability

In this procedure, 50 grams of freshly prepared foam was introduced into a graduated cylinder and left for 30 minutes. The volume of the liquid that dripped out, referred to as the drainage volume, was then recorded [16].

2.5.2. Foamability properties

Overrun (also called foamability or foaming capacity) described as the increase in foam volume compared to initial mixture, was calculated immediately post-production of foam utilizing a weight-based methodology [17].

)Eq. 2(

$$\%\text{Overrun}=\frac{v_2-v_1}{v_1}$$

Where v_2 is the volume of the foam immediately after stirring and v_1 is the initial volume of the solution.

2.6. Experiments of drying process

2.6.1. drying kinetics

Orange pulp foams with a uniform thickness of 4 mm were poured into aluminum containers, placed in a hot air dryer, and subjected to temperatures of 40, 55, and 70 °C. At specified time intervals, the samples were removed from the air dryer and their weight was recorded using a digital scale with a precision of 0.01 g. This procedure was repeated until the samples reached a constant weight [18].

The following equation was used to calculate the drying speed:

(Eq. 3)

$$DR = \frac{M - M_{t+\Delta t}}{\Delta t}$$

Where $M_{t+\Delta t}$ is the moisture content based on dry matter at time $t + \Delta t$, t is time (min), and Δt indicates the time difference (min).

2.6.2. Effective diffusion coefficient

The effective diffusion coefficient which is calculated using Fick's second law is a valuable tool to describe the drying process and potential mechanisms involved in moisture transfer in foods.

(Eq. 4)

$$\frac{\partial M}{\partial t} = D_{eff}\frac{\partial^2 M}{\partial r^2}$$

In this context, **M** is the amount of moisture based on dry matter, D_{eff} is the effective diffusion coefficient of moisture (m^2/s), **L** represents the spatial characteristic of moisture transfer, and **t** is the drying time. Fick's law requires two

parameters: the sample size and the effective diffusion coefficient.

An infinite slab geometry is used to calculate the transport of moisture during drying, from the center of the foam to its surface. Consequently, the moisture removal can be calculated using the following equation:

(Eq. 5)

$$MR = \frac{8}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{(2n-1)^2}\exp\left(-\frac{(2n-1)^2\pi^2 D_{eff}t}{4L^2}\right)$$

Here, **MR** represents the moisture ratio, **n** (which can be 1, 2, 3, etc.) is the number of terms taken into consideration, **t** is the drying time (in seconds), D_{eff} is the effective diffusion coefficient of moisture (m²/s), and **L** is the thickness of the foam (m).

The value of the MR parameter was determined using the values of initial moisture (M_i), equilibrium moisture (M_e), and the moisture at each moment (M), according to the following equation:

(Eq. 6)

$$MR = \frac{M - M_e}{M_i - M_e}$$

For long drying times, the terms in the infinite series of the above simplified equation converge and can be approximated with the first term of the series, which can be written in logarithmic form [19].

(Eq. 7)

$$\ln(MR) = \ln\left(\frac{8}{\pi^2}\right) - \left(\frac{\pi^2 D_{eff}t}{4L^2}\right)$$

By plotting a diagram of Ln (MR) against drying time, a straight line with a slope of K is obtained, which is used to calculate the moisture effective diffusion coefficient:

(Eq. 8)

$$k = \frac{\pi^2 D_{eff}}{4L^2}$$

2.7. Foam experiments

2.7.1. Water activity

2 g of the powder was placed in a special container of the aw meter device and left to equilibrate. The water activity was then recorded at a temperature of 25 °C [14].

2.7.2. solubility of powder

1 g of the produced powder was dissolved in 100 ml of water, and the resulting solution was homogenized using an Ultrathorax (IK, Germany) for 5 minutes at 15000 rpm. Next, to separate the insoluble parts, the mixture was centrifuged at 3000 rpm for 10 min. Then, 25 ml of the transparent phase from the test tube was extracted and placed in an oven at 105 °C for 5 hours. The solubility of the powder was calculated using the following equation:

(Eq. 9)

$$S = \frac{m_2 - m_1}{0.25}\times 100$$

Here, S, m1, and m2 were the solubility, the weight of the empty

container, and the weight of the container after drying in oven for 5 h [20].

2.7.3. powder density

3 grams of powder were placed in a 25 ml graduated cylinder and its volume was recorded. The desired powder density was obtained by dividing the weight by its volume [21].

2.7.4. color analysis

The color of the samples was measured using a Chromameter, and color parameters including L*, a*, and b* were analyzed. Before measuring these color parameters, the device was calibrated using a standard white tile (L*=98.14, a*=0.23, b*=1.89). The color of the powders was then evaluated in the L*a*b** color space [22].

2.7.5. water holding capacity

The water holding capacity was measured based on the following equation [18]:

(Eq. 10)

$$\frac{A-B}{C} = \text{ظرفیت جذب آب}$$

Here, **A** is the amount of water added to the powder before centrifugation (g), **B** is the water discarded after centrifugation (g), and **C** is the weight of the powder sample (g).

2.7.6. DSC

A differential scanning calorimeter (400-Ci, Sanaf, Iran) was used to measure the glass transition temperature.

2.8. Statistical analysis

The foam test data were analyzed using a 3x3 factorial design in a completely randomized design with three replicates. SPSS software, version 16, was used to analyze the data. Duncan's multiple range test at a 95% significance level ($p<0.05$) was used to compare means. All charts and graphs were drawn using Microsoft Excel 2013 [18].

3- results and discussion

3. foam properties

3.1.1. overrun

As per the results delineated in Table 2, it is evident that the A4B1 treatment, possessing an overrun (foamability) of 308%, significantly exhibited the highest overrun, while the A1B3 treatment, with an overrun of 75%, demonstrated the lowest overrun among all samples. According to the results, the A1B1, A1B2, A1B3, A2B3, and A2B1 treatments had the least overrun, i.e., increase in volume, indicating that this parameter was significantly lower in these samples. Generally, an increase in gum concentration corresponded to a decrease in overrun. The reduction in overrun can be attributed to the increase in the viscosity of the solution. This means that a solution with lower viscosity requires less shear force for stirring and aeration, which favors the consistent and uniform distribution of air bubbles within the solution without any disintegration [23]. However, with an increase in protein concentration from 1 to 4%, the overrun increased. An increase in the quantity of egg white protein expedites the absorption of protein at the air-liquid interface, thereby reducing surface tension and enhancing foaming ability. Egg white is well-known for its remarkable foaming capacity properties since it contains proteins with high amphiphilic properties [24].

3.1.2. foam stability

Based on the results presented, it is evident that treatments A1B3, A2B3, A3B3, and A4B3, all exhibiting almost no drainage, were the most stable foams. The drainage observed in sample A1B1, i.e., 31 ml, was significantly higher than other treatments, indicating a higher foam instability in this sample. The results underscored the pivotal role of *Lepidium sativum* gum in enhancing foam stability ($P<0.05$). An increase in the concentration of *Lepidium sativum* gum led to an elevation of the solution viscosity, thereby improving the viscoelastic and elastic properties of the foam bubble walls. This enhancement bolstered the resistance of the bubble wall, consequently augmenting the robustness of the foam structure and preventing bubble collapse [25]. The increase in the viscosity of the liquid phase facilitated the formation of a network structure within the continuous phase, consequently protecting the bubble wall from disintegration and enhancing the stability of the foam [26].

On the contrary, an increase in the concentration of egg white protein resulted in a significant reduction in the drainage volume ($P<0.05$). The increase in the concentration of the foaming agent led to an enhancement in viscosity, thereby thickening the solution and augmenting the resistance of the absorption films at the air-water interface as well as strengthening the boundary layer (via electrostatic, hydrogen, covalent, and hydrophobic forces) [27]. Furthermore, an increase in protein concentration amplified the interaction between protein molecules, thereby inducing an increase in viscosity [24]. The egg white protein, owing to its ability to form a cohesive and viscous film, facilitates the production of foam with high stability [24].

3.1.3. foam density

Based on the obtained results, it is evident that there exists an inverse relationship between density and overrun. Specifically, the A4B1 treatment, with a density of 0.21 g/cm³, exhibited the lowest density, while the A1B3 treatment, with a density of 0.655 g/cm³, demonstrated the highest foam density. The foam density significantly diminished with an increase in protein concentration. The foamability is contingent upon the molecular size and structure of the protein. Owing to the fact that egg white protein has balanced hydrophilic and hydrophobic groups and is capable of reducing surface tension, it can accelerate the reduction of interfacial tension, thereby leading to a decrease in density [23]. According to the foam density results, an increase in the concentration of *Lepidium sativum* gum had a detrimental impact on foam density, resulting in an increase in foam density. An increase in gum concentration can enhance the viscosity of the solution, thereby inhibiting the entry of air and reducing the volume of air entrapped in the mixture. This, in turn, limits the expansion and consequently increases the density of the foam [8].

Table 2 Effect on gum concentration and protein concentration on stability, overrun and density of orange foam

Treatment	Stability (cc)	Density (gr/cm^3)	Overrun (%)

A1B1	31± 1[a]	0.385 ± 0.005[c]	۱۰۸ ± ۲[c]
A1B2	14.5± 1.5[b]	0.495 ± 0.005[b]	۸۴ ± ۰[c]
A1B3	۰ ± ۰[c]	0.655 ± 0.015[a]	۷۵ ± ۳[c]
A2B1	۱۰ ± ۱[b]	0.425 ± 0.005[bc]	۱۱۶ ± ۱[c]
A2B2	۱ ± ۱[c]	0.305 ± 0.005[d]	۱۸۶ ± ۵[b]
A2B3	۰ ± ۰[c]	0.41 ± 0.02[c]	۱۲۶ ± ٤[c]
A3B1	۹ ± ۱[b]	0.265 ± 0.015[de]	۲۲۹ ± ٤[b]
A3B2	1.5±0.5[c]	0.275 ± 0.015[de]	۲۲۳ ± ۲[b]
A3B3	۰ ± ۰[c]	0.3± 0.01[d]	۲۰۴ ± ٤[b]
A4B1	0.5 ± 0.5[c]	0.21 ± 0.01[e]	۳۰۸ ± ٤[a]
A4B2	0.5± 0.5[c]	0.26 ± 0.02[de]	۲۳۶ ± ۲[b]
A4B3	۰ ± ۰[c]	0.28 ± 0.01[de]	۲۲۶ ± ۳[b]

3.2. selecting optimal treatment for foam preparation

To choose the best foam for drying, parameters including highest stability (lower drainage rate), lowest density, and highest overrun were considered [28]. The results revealed that A4B1, which exhibited the best stability (drainage volume of 0.5 ml), the lowest density (0.21 g/cm³), and the highest overrun (308 ml), was deemed the best treatment for orange powder production.

3.3. drying kinetic

Figure 1 illustrates the variation in the humidity ratio of the samples produced at varying temperatures (40 to 70 °C). It is evident from Figure 1 that there is a consistent decrease in moisture content over time. Furthermore, the data indicates a significant reduction in drying time with an increase in temperature from 40 to 70 °C. Specifically, the drying times at 40, 55, and 70 °C were recorded as 280, 150, and 100 min, respectively.

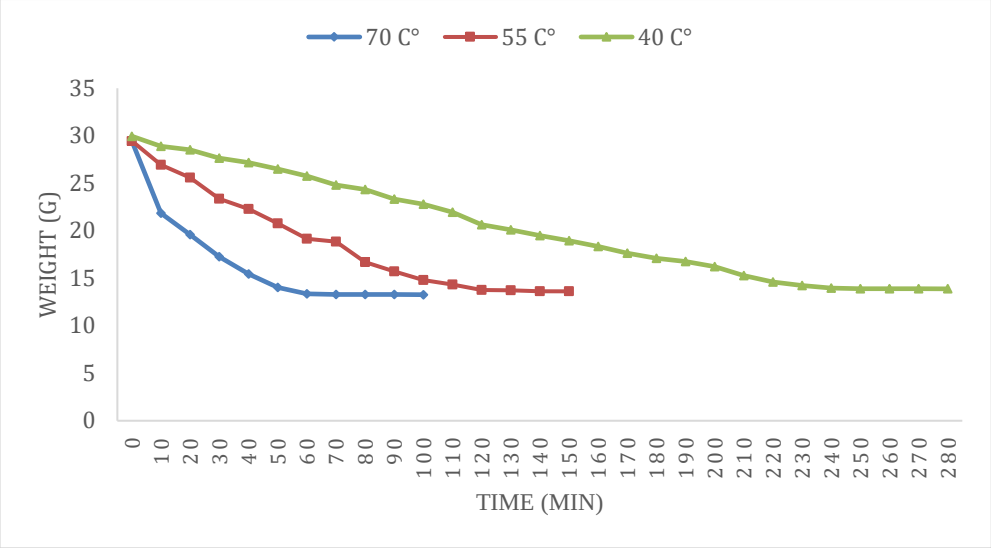

Figure 1 The effect of drying temperature on orange foam weight

The changes of Ln moisture ratio and drying time at different temperatures are shown in Figure 2.

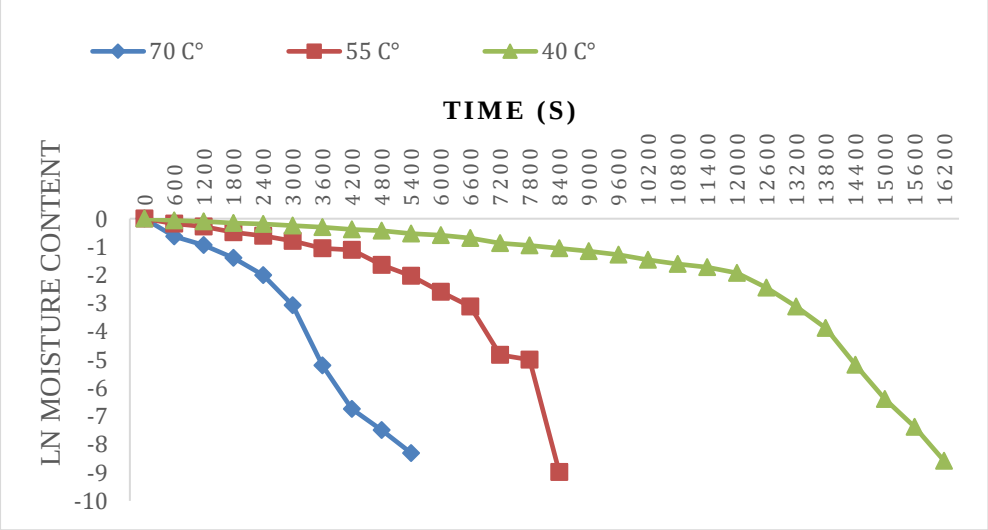

Figure 2 Changing of the moisture content of orange foam (Ln) and drying time in different temperature

Table 3 presents the effective diffusion coefficients of foam moisture at 40, 55, and 70 °C. The results show a positive correlation between temperature and the effective diffusion coefficient of moisture. Specifically, an increase in temperature led to an increase in the effective diffusion coefficient of moisture; this can be attributed to the interactions between molecules and the pronounced influence of temperature in facilitating molecular motion. Similar findings regarding the effective moisture diffusion coefficient of tomato juice, ranging from $2.026 \times 10^{-8}\ m^2/s$ to $3.039 \times 10^{-8}\ m^2/s$, have been reported by Kadam et al. [29].

Table 3 Regression equation and moisture effective diffusion coefficient of orange foam

b	A	L	Temperature (°C)
26.47 ±0.31[a]	-7.425 ±0.095[c]	69.385± 0.345[c]	40
23.485±0.235[b]	-6.3± 0.31[b]	76.115 ± 0.245[b]	55
19.425 ± 0.285[c]	-3.69± 0.17[a]	79.495 ± 0.565[a]	70

3.4. foam characteristics

3.4.1. color analysis

Table 4 depicts the impact of drying temperature (45 to 70 °C) on the color parameters, L*, a*, and b*. The data showed a significant increase in the L* value with the increase in the drying temperature, the sample prepared at 70°C had the highest L*. In terms of the a* parameter, results showed that with increasing drying temperature, the a* parameter increased, which means that greenness significantly decreased while the redness increased. As for the b* parameter, this parameter exhibited a decrease with the rise in temperature. At lower temperatures, reaction rates were lower, compared to higher temperatures. The longer drying process at 40°C at this low temperature, amplified the browning reactions, thereby samples prepared at this temperature showed darkened color compared to those at 55°C. Conversely, drying the sample at a higher temperature resulted in an increase in the L* value since the foam during drying had less contact with oxygen [18].

Table 4 Effect of drying temperature on orange powder color

Effective diffusion (m^2/s)coefficient	R^2	Regression equation	Temperature (°C)
$^{-7}$، 1 × 1.387	0.707	-0.238x+1.5708	40
$^{-7}$،1 × 2.551	0.758	-0.478x+1.6523	55
$^{-7}$،1 × 2.938	0.948	-0.995x+1.8964	70

3.4.2. powder solubility

Figure 3 shows the influence of drying temperature on the solubility of orange powder. The data suggests that an increase in drying temperature corresponds to an increase in the solubility of the orange powder. Notably, the solubility of an orange juice sample dried at 70°C was significantly higher than that at other temperatures ($P<0.05$). This phenomenon could be attributed to the shorter time needed for drying. This means that as the drying temperature increased from 40 to 70 °C, drying time decreased, so, the

possibility of bubble collapse and degradation over a longer time decreased. In addition, with shorter drying time, the porous structure of the foam is better preserved, which directly impacts the solubility. A similar trend was observed by Goula and Adampoulos [30] in their study on tomato powder. These researchers stated that the enhancement in powder solubility as a result of increased dryer temperature is directly associated with the way the moisture is transferred out from the foam texture and the moisture content of the sample.

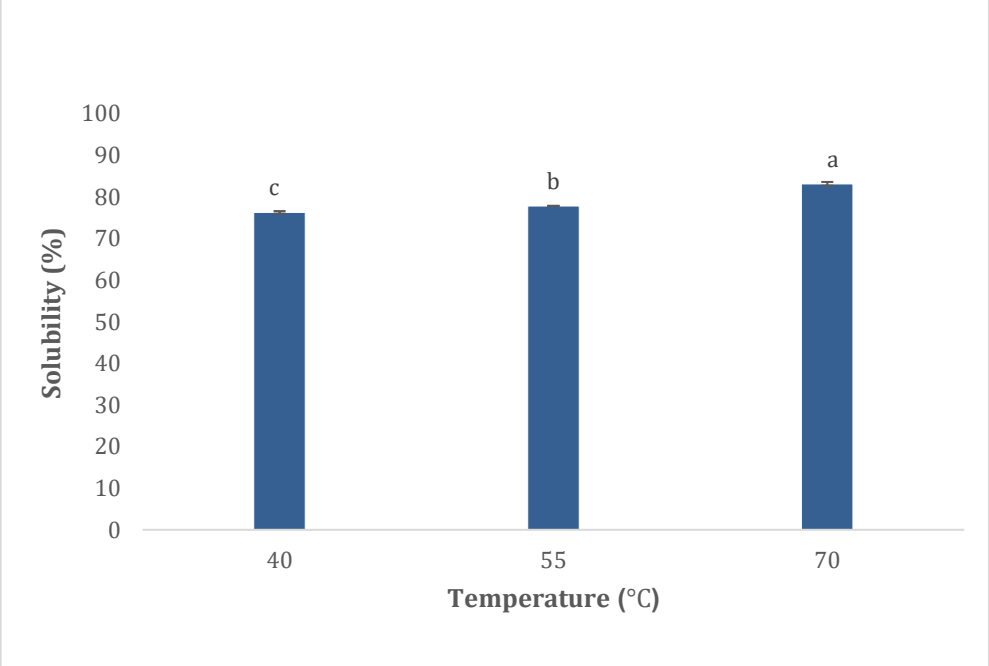

Figure 3 The effect of drying temperature on orange powder solubility

3.4.3. powder density

Figure 4 presents the findings of the influence of drying temperature on the density of orange powder. The data indicates that an increase in temperature from 40 to 70°C corresponded to a decrease in the density of the powder. Notably, the density was significantly lower in the sample dried at 70°C compared to the other samples. This reduction in density at elevated temperatures can be attributed to the accelerated drying process at these temperatures. The density, akin to the moisture content, improves the rate of heat transfer into the structure of the floor by increasing the temperature differential between the floor and the drying air. Consequently, the powder is produced with a lower moisture content and, hence, a reduced density [31].

3.4.3. powder density

Figure 4 presents the findings pertaining to the influence of drying temperature on the density of orange powder. The data indicates that an increase in temperature from 40 to 70°C corresponded to a decrease in the density of the powder. Notably, the density was significantly lower in the sample dried at 70°C compared to the other samples. This reduction in density at elevated temperatures can be attributed to the accelerated drying process at these temperatures. Similar to moisture content, the density decreased as the difference

between the foam temperature and the drying air increased, which improved the rate of heat transfer from the foam structure. Consequently, the powder was produced with a lower moisture content and, hence, a reduced density [31].

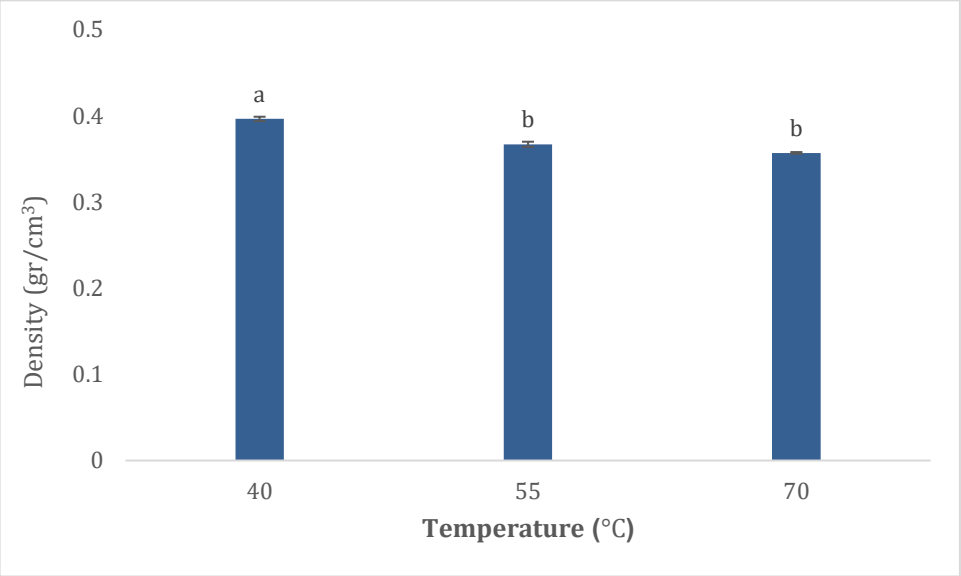

Figure 4 The effect of drying temperature on orange powder density

3.3.4. Rehydration properties

Figure 5 presents the findings pertaining to the influence of drying temperature on rehydration of samples. The data suggests that an increase in temperature from 40 to 70°C corresponded to a decrease in the water rehydration capability. Notably, this parameter was significantly lower in the sample dried at 70°C compared to the other samples. This reduction in water reabsorption with escalating temperature can be attributed to the denaturation of egg white proteins. When egg white proteins denatured under high temperatures, hydrophobic groups of proteins presented on the protein surface which led to a decrease in the powder rehydration ability. In cases where denaturation occurs on a large scale, protein molecules may aggregate and interact, thereby reducing the area of the protein that can interact with water molecules, and consequently reducing its water rehydration properties [18].

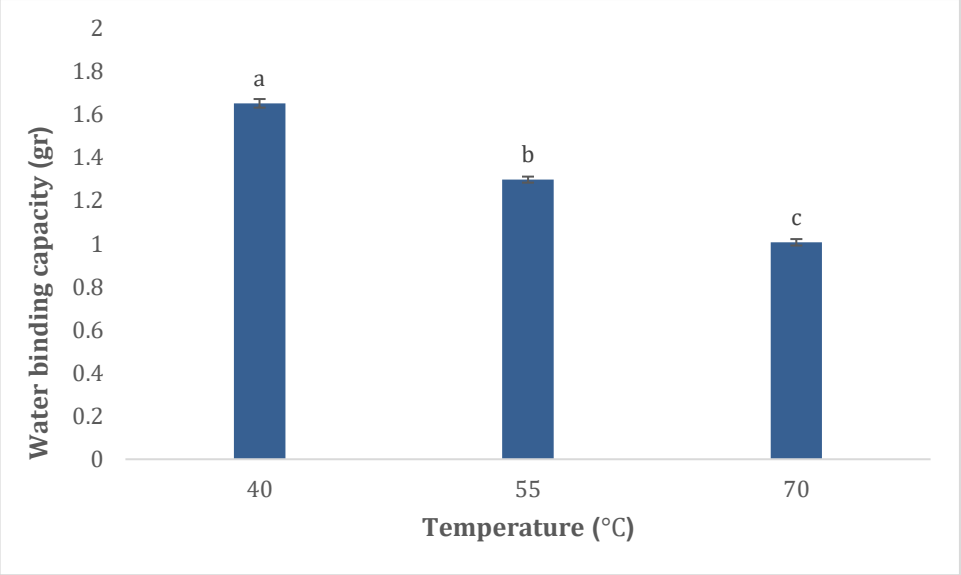

Figure 5 The effect of drying temperature on water binding capacity of orange powder

3.3.5. water activity

Figure 6 demonstrates the findings of the influence of drying temperature on the water activity of orange powder samples. The data suggests that an increase in temperature from 40 to 70°C corresponded to a decrease in water activity. This parameter was significantly lower in the sample dried at 70°C compared to the other samples. At elevated temperatures, the differences between the foam temperature and the hot air increased, thereby enhancing the rate of heat transfer. Consequently, the powders produced at higher temperatures exhibited lower water activity.

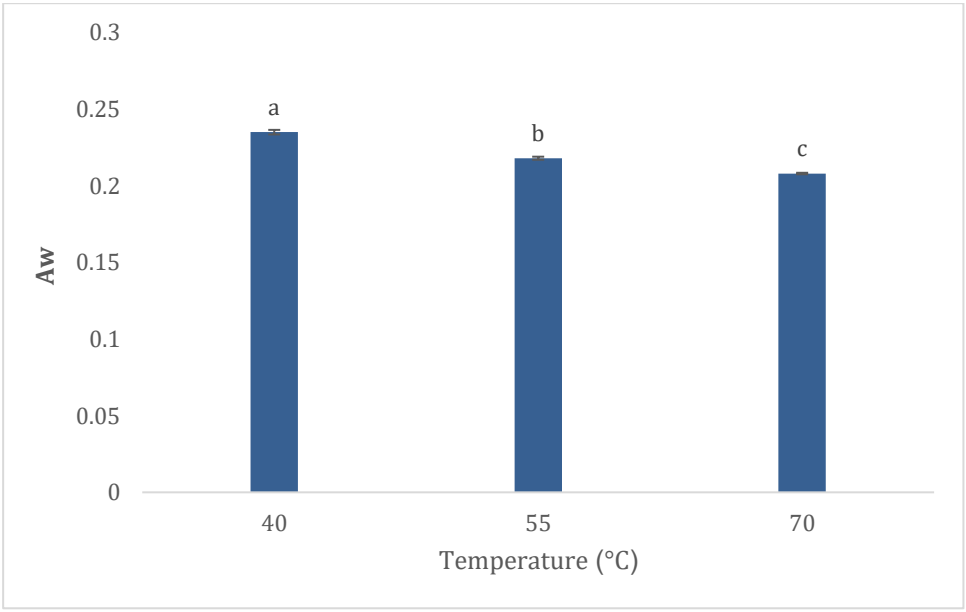

Figure 6 The effect of drying temperature on water activity of orange powder

3.3.6. DSC

Glass transition temperature (Tg) values of orange powder produced at different drying temperatures are presented in Figure 7. Tg values serve as an indicator of the powder's stability during production. The data suggests that the powder produced at higher temperatures exhibits superior heat resistance compared to that produced at lower temperatures. A decrease in the drying temperature, attributed to the

difficulties in heat transfer and consequently higher moisture content, led to a reduction in the Tg values of the produced powders.

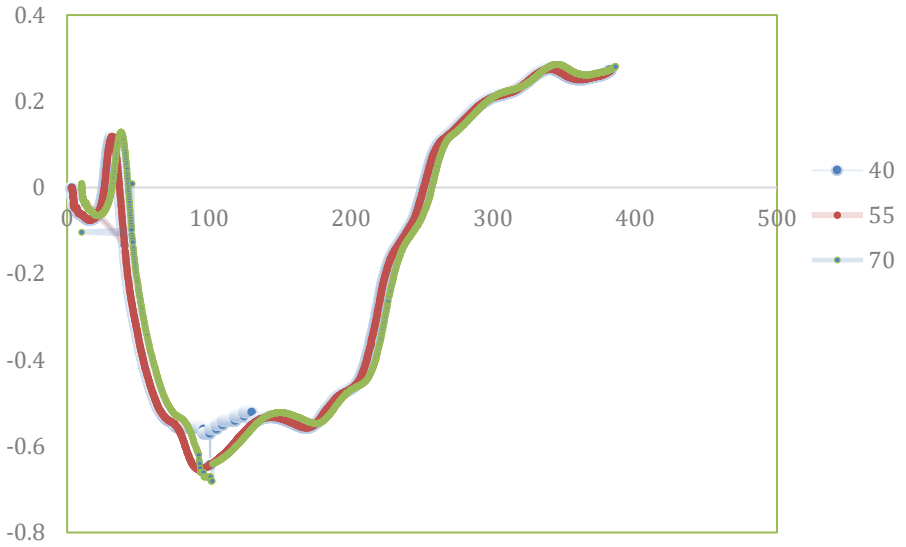

Figure 7 Effect of drying temperature on the DSC thermogram of orange powder

4- conclusion

This study investigated the effects of *Lepidium sativum* gum at 3 concentrations (0.1%, 0.2%, and 0.3%) as a stabilizer and egg white powder at 4 concentrations (1%, 2%, 3%, and 4%) as a foaming agent on the properties of foam mat dried orange juice and the best sample was chosen for drying. The impact of drying temperature at 3 levels (40, 55, and 70 °C) on the properties of the resultant orange juice powder (including solubility, rehydration, water activity, density, and color) produced via the foam mat drying method was examined. Additionally, the drying kinetics of the samples were modeled. The findings indicated that a decrease in the concentration of *Lepidium sativum* gum and an increase in the concentration of egg white powder significantly increased the overrun and decreased the density of the foams. Furthermore, an increase in the concentration of both *Lepidium sativum* gum and egg white protein enhanced the foam stability. Among all treatments, the sample containing 4% egg white powder and 0.1% *Lepidium sativum* gum was selected as the optimal treatment for the preparing orange powder since it had low drainage (0.5 ml), low density (0.321 gr/cm³), and high overrun (308 ml). The drying time of the orange pulp at temperatures of 40, 55, and 70 °C was recorded as 280, 150, and 100 min, respectively. The effective diffusion coefficient in the temperature range of 40 to 70 °C ranged from $1.38 \times 10^{-7}\ m^2/s$ to $2.938 \times 10^{-7}\ m^2/s$. The results demonstrated that an increase in temperature from 40 to 70 °C led to an increase in the powder's solubility, while the water activity, density, and water rehydration ability of the powder significantly decreased ($p<0.05$). Moreover, the color analysis results revealed that an increase in drying temperature significantly increased the color parameters of L* and a*, and a decrease in the b* parameter.

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مقاله علمی_پژوهشی

بررسی فرآیند خشک کردن آب پرتقال به روش خشک کردن کف پوشی با استفاده از صمغ بومی شاهی و آلبومین تخم مرغ

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اطلاعات مقاله

تاریخ های مقاله :

تاریخ دریافت: ۱۴۰۲/۸/۶

تاریخ پذیرش: ۱۴۰۲/۱۰/۱۶

کلمات کلیدی:

پرتقال،

خشک کردن کف پوشی،

صمغ شاهی،

پروتئین،

خواص پودر

DOI: 10.22034/FSCT.21.147.131.

مسئول مکاتبات: *

چکیده

در این پژوهش از صمغ دانه شاهی در سه غلظت (۰/۱، ۰/۲ و ۰/۳ درصد) به عنوان پایدارکننده و پودر سفیده تخم مرغ در چهار سطح (۱، ۲ ، ۳ و ٤ درصد) جهت تولید کف آب پرتقال استفاده گردید و سپس نمونه بهینه کف (حداقل دانسیته، حداکثر پایداری و افزایش حجم) انتخاب شد. در ادامه نمونه بهینه جهت خشک کردن به روش کف پوشی، در سه دمای مختلف (٤۰، ۵۵ و ۷۰ درجه سانتی گراد) توسط خشک کن هوای داغ خشک شد. نتایج نشان داد که با کاهش غلظت صمغ دانه شاهی و افزایش غلظت پروتئین سفیده تخم مرغ، اوران کف به صورت معنی داری افزایش یافت و مقدار دانسیته کم شد($p<0.05$) . همچنین با افزایش غلظت صمغ دانه شاهی و پروتئین سفیده تخم مرغ، پایداری کف بهبود یافت. در بین تمامی تیمارها، نمونه حاوی ٤ درصد پودر سفیده تخم مرغ و ۰/۱ درصد صمغ دانه شاهی علاوه بر زهکشی کم (حجم زهکشی ۰/۵ میلی لیتر)، دارای دانسیته پایین (۰/۲۱gr/cm^3) و اوران بالایی (۳۰۸ درصد) بود که به عنوان بهترین تیمار جهت تولید پودر پرتقال انتخاب شد. زمان خشک شدن کف پرتقال در دماهای ٤۰، ۵۵ و ۷۰ درجه سانتی گراد به ترتیب ۱۰۰، ۱۵۰ و ۲۸۰ دقیقه بود. ضریب نفوذ موثر در بازه دمایی ٤۰ تا ۷۰ درجه سانتی گراد در محدوده $۱۰^{-۷} \times ۱/۳۸$ تا $۲/۹۳۸\times۱۰^{-۷}$ مترمربع بر ثانیه قرار داشت. نتایج نشان داد با افزایش دما از ٤۰ به ۷۰ درجه سانتی گراد، حلالیت پودر افزایش یافت در حالیکه فعالیت آبی پودر، دانسیته و قابلیت جذب مجدد آب به شکل معنی داری کاهش پیدا کرد ($p<۰/۰۵$). همچنین نتایج حاصل از آنالیز رنگ نشان داد که با افزایش دمای خشک کردن، شاخص های رنگی (L^*) و (a^*) به صورت معنی داری افزایش یافتند و شاخص رنگی (b^*) کاهش یافت. یک جمله نتیجه گیری اضافه شود.