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ASSESSMENTS OF KINETICS, ENERGY ANALYSIS, AND DENSITY-FLOW PROPERTIES OF ONION POWDER PROCESSING BY CONVECTIVE DRYING

Muhammed TAŞOVA [1]

[1] *Tokat Gaziosmanpaşa University, Department of Biosystems Engineering, Tokat, Türkiye*
muhammed.tasova@gop.edu.tr

ABSTRACT

In this study, the effects of NaCl used at rates of 0, 10, 20, and 30% on energy consumption, milling process efficiency, and physical-flow properties of onion production processes were investigated. The effective diffusion value was found to vary between 2.86×10^{-6} and 9.97×10^{-7} m^2/s. *SMER* and *SEC* values varied between 0.00175 - 0.000303 kg/kWh and 570 - 3299.27 kWh/kg, respectively. Evaporation energy values were determined to range between 3.16 - 2.15 kWh. The highest density values were determined at a 30% NaCl rate. The best *CI* and *HR* values were determined at a 10% NaCl rate. The highest dry matter and lowest moisture rates were determined for carrier agents used at 30% and 0%, respectively. The minimum wetting time was defined as 6 ± 1.00 seconds for the carrier agent, which is used at a rate of 30%.

Keywords: Onion powder, Flow property, Physical property, Energy consumption, Drying kinetics.

1 INTRODUCTION

The moisture is removed from powder products, there is a decrease in weight and volume. Products converted into food powder are easier to process than their fresh state [2] and their sensory properties are intensified and used in many areas. The most important thermal process applied in food powder production is drying. The main purpose of drying processes is to prevent deterioration in the products due to oxidative and non-enzymatic reactions. However, it is desired to preserve the product's taste, aroma, and color properties. One of the drying processes is convective hot air (*CD*) drying [6]. The CD method is widely used method in food powder production [7].

Caking is a big problem in the food powder production process. The sugar contained in the products becomes thermoplastic during drying. This situation creates the problem of stickiness in powders. Stickiness causes food powder to clump. Flocculation causes problems in the storage, spillage, pulverization (grinding process efficiency), and marketing processes of the powder. Some substances (carrier agents) are used to reduce or eliminate the clumping phenomenon that occurs in food powder production. In food powder production processes, carrier agents such as maltodextrin [9], inulin [10], gum arabic [11], and whey protein [12] are generally preferred. These substances and the ratios used have different effects on food powders. In the literature; Michalska-Ciechanowska et al. [9] used maltodextrin agent to produce powder from cranberry fruit juice. They investigated the effect of carrier agents on the physicochemical properties of the produced food powder. They found that as the rate of maltodextrin used increased, the gloss value of the powder increased and the moisture content decreased. Tkacz et al. [10] used inulin to produce seawater powder. In the study conducted using the vacuum drying system, it was found that the food powder produced had a lower moisture value than the others. Li et al. [11] investigated the effect of gum arabic added at the rates of 0, 5, 10, and 15% in melon powder production studies. They investigated some properties of food powders produced by the foam drying technique. They found that the powder had low density, high expansion, and high foam stability when 10% Arabic gum was added. In his study, Minh [12] investigated the effects of whey protein and other carrier agents on the physicochemical properties of citron powder. They found that bulk density values, total phenol, moisture content, ascorbic acid, and water activity were higher when whey protein was used compared to other substances. No comprehensive study has been found investigating the effects of sodium chloride (NaCl), which is used as an economical carrier agent, on the grinding process efficiency, physicochemical properties, and energy consumption parameters of onion powder.

In this study, the effects of sodium chloride (NaCl) with the rates of 0, 10, 20, and 30% (1) used in onion powder production processes on the drying properties, modeling, effective moisture diffusion (2), and drying kinetics (moisture content and drying rate) of the produced food powder were investigated. Its effects on moisture content, grinding process efficiency, compressed wettability, flow properties (Hausner-carr index), and bulk density (3), energy efficiency, evaporation energy, and energy consumption (*SMER*, *SEC*) (4), and color (5) values were investigated.

2 MATERIAL AND METHOD

2.1 Raw material

Fresh onions were purchased from a local market. The sodium chloride (NaCl) substance used in the solidification of food powder was used, which is produced by Med-Mar Health Services, Food, Construction, Tourism, Salt Management, Transportation and Electricity Production Industry Trade Inc. (Türkiye).

2.2 Preparation of Puree and Mixture

Fresh onions were processed into puree using a food processor. Mixtures were prepared by adding 0%, 10%, 20%, and 30% sodium chloride to the samples, respectively. Mixture samples were 0% (125 g puree+0 g NaCl), 10% (112.50 g+12.50 g NaCl), 20% (100 g puree+25 g NaCl), and 30% (87.50 g puree+ 37.50 gr NaCl).

2.3 Moisture Content

The initial water content of the puree was calculated with the method of Kaveh et al. [13].

2.4 Drying Processes

The products were dried to turn them into powder. The samples were dried at 70 ºC [14] until the moisture change stabilized.

2.5 Drying Rate

Drying rate (DR) values of the samples were determined using Equation 1 [15].

$$DR = \frac{M_t - M_{(t+dt)}}{d_t} \quad (1)$$

Here: M_t; moisture content, d_t; minutes, DR; drying rate (g moisture.g dry matter min).

2.6 Moisture Rate

Moisture rate (MR) values of the samples were determined using Equation 2 [16].

$$\mathrm{MR} = \frac{\mathrm{M} - \mathrm{M_e}}{\mathrm{M_0} - \mathrm{M_e}} \quad (2)$$

Here: *MR*; moisture rate, M; moisture content, M_e; Equilibrium moisture content, M_o; initial moisture content.

2.7 Mathematical Model

The experimental humidity values determined depending on the time were processed in thin-layer mathematical models and the most suitable model was determined to determine the time-humidity ratio relationship.

Lewis	$MR = \exp(-k.t)$	Lewis [17]	(3)
Jena-Das	$MR = k.\exp(-h.t + j(t^{0.5}) + m)$	Jena and Das [18]	(4)
Wang-Sıng	$MR = 1 + k.t + h.t^2$	Wang and Singh [19]	(5)

Here: h, j, k, m; coefficients of modules, t; duration

2.8 Effective Diffusion

Effective moisture diffusion (D_{eff}) values of the samples were determined using Equation 6 [20].

$$\ln MR = \ln\frac{8}{\pi^2} - \frac{\pi^2 \cdot D_{eff \cdot t}}{4L^2} \quad (6)$$

Here: D_{eff}; effective moisture diffusion value ($m^2.s^{-1}$), L; thickness value (m).

2.9 Specific Moisture Extraction Rate

Specific moisture extraction rate (SMER) values of the samples were determined using Equation 7 [21].

$$SMER = \frac{m_w}{E_t} \quad (7)$$

Here: *SMER*; specific moisture removal rate ($kg.kWh^{-1}$).

2.10 Specific Energy Consumption

Specific energy consumption (SEC) values of the samples were determined using Equation 8 [22].

$$SEC = \frac{E_t}{m_w} \tag{8}$$

Here: SEC; specific energy consumption ($kWh.kg^{-1}$), E_t; total consumed energy (kWh), m_w; amount of water removed (kg).

2.11 Evaporation Energy

Evaporation energy values of the samples were determined using Equation 9 [23].

$$Qw = h_{fg} \times m_w \tag{9}$$

$$hfg = 2.503 \times 10^6 - 2.386 \times 10^3 \times (T_d - 273.16)$$

$$273.16 \leq T_d(K) < 338.72$$

$$h_{fg} = \sqrt{(7.33 \times 10^{12} - 1.60 \times 10^7 \times T_d^2)}$$

$$338.72 \leq T_d < 533.16$$

Here: Q_w; evaporation energy (kWh), h_{fg}; latent energy of evaporation ($kJ.kg^{-1}$), T_d; drying temperature (K).

2.12 Onion Powder

The dried onion flakes were ground using a blender. The grinding process was carried out for 2 minutes.

2.13 Grinding Processes Efficiency

The efficiency rate of the onion powder production process was calculated according to the method in Pui et al. [25]. Equation 10 was used to determine the efficiency ratio of the powder production process.

$$Process\ efficiency\ (\%) = \frac{Powder\ weight}{Dried\ puree\ weight} \times 100 \tag{10}$$

Here; Powder weight denotes the amount (g) obtained after grinding. Puree weight, on the other hand, indicates the total amount (g) in dry form before grinding.

2.14 Density Properties

The compacted and bulk density values of the powders were determined according to Sejali and Anuar [26].

2.15 Flow Properties

Determination of the flow characteristics of onion powder is important in the pulverization and transportation processes. Equations 11 and 12 were used in the calculation of Carr and Hausner indices, respectively.

Carr index

$$CI = \frac{Pt - Pb}{Pt} \times 100 \quad (11)$$

Here; CI: Carr, P_t: tapped, P_b: bulk.

CI index;

1) % 5 < CI < % 15

The pourability of onion powder is very good.

2) % 15 < CI < % 25

The Pourability of onion powder is normal.

3) % 25 ≤ CI

The pourability of onion powder is very poor.

Hausner index

$$HR = \frac{Pt}{Pb} \quad (12)$$

HR index;

1) HR > 1.40

Onion powder has high stickiness (level C).

2) 1.40 > HR > 1.25

Onion powder has medium stickiness (level C-A).

3) 1.25 > HR > 1

Onion powder has low stickiness (level A).

Here; HR: Hausner, P_t: Tapped, P_b: Bulk values.

2.16 The Moisture Content of the Powder

Moisture content was determined with the method of Kaveh et al. [13]. It was determined using Equation 13 to determine the moisture content of the onion powders.

$$Nd.w. = \frac{Initial\ weight - Last\ weight}{Last\ weight} \quad (13)$$

2.17 Dry Matter Rate

Dry matter content was calculated with the method Kaveh et al. [13].

2.18 Wettability

The wettability value was determined according to the method specified by Gong et al. [27].

2.19 Color

The color properties of the powders were determined. Equations (14-16) were used to calculate these values [28-30].

$$C = (a^2 + b^2)^{1/2} \quad (14)$$

$$\mathrm{h}° = \tan^{-1}(\frac{\mathrm{b}}{\mathrm{a}}) \quad (15)$$

$$\Delta\mathrm{E} \ = \sqrt{(\mathrm{L} - \mathrm{L}*)^2 + (\mathrm{a} - \mathrm{a}*)^2 + (\mathrm{b} - \mathrm{b}*)^2} \quad (16)$$

Here *L*: brightness, *a*: red-green, *b*: yellow-blue, *C*: Chroma, *Hue*: Hue angle, ΔE: Total color change. *L**: brightness for dried products, *a**: red-green for dried products, *b**: yellow-blue for dried products.

2.20 Statistical Analysis

SigmaPlot10 was used to create the drying models of dried onion puree ($p<0.05$). Duncan's multiple comparison test ($p<0.05$) was performed in the SPSS17 program to evaluate the measured color values statistically.

3 RESULTS AND DISCUSSION

3.1 Drying Kinetics

The drying curves are given in Figure 1.

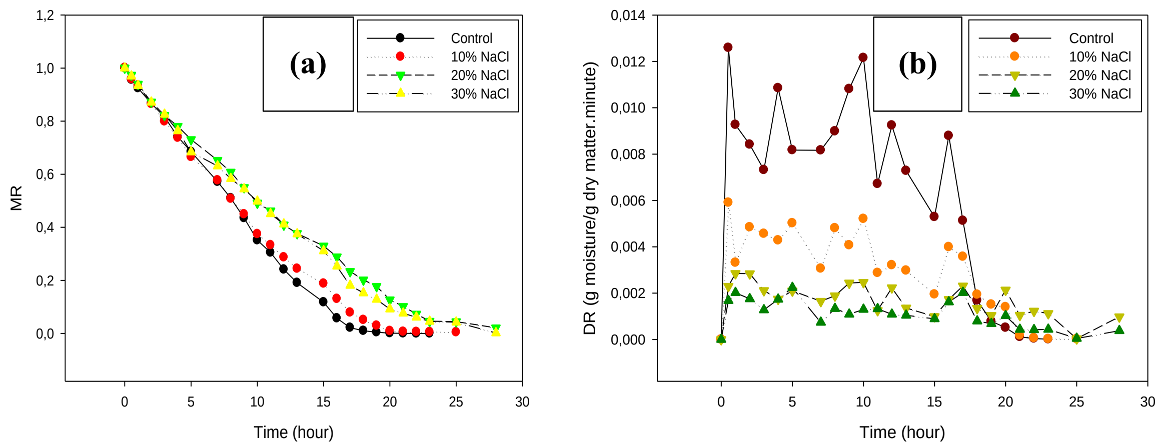

Figure 1. (a) Moisture rate; (b) Drying rate.

NaCl added to the samples affected the drying and moisture rates of the carrier agent. According to Figure 1, control (0% NaCl) samples dried in the shortest time. It was observed that drying time increased with increasing NaCl ratios. Although NaCl had an osmotic effect on the samples, it had a barrier effect against moisture, making it difficult to remove it. The average drying times of the samples to which carrier agent was added at 0% (control), 10%, 20%, and 30% were determined as 23, 25, 26, and 28 hours, respectively. The average drying rates of the samples were found to vary between 0.0063 - 0.0010 g moisture/g drying agent.minute. Farooq et al. [31] used 0, 4, 8, and 12% soy protein powder in the production of onion powder. When compared to the control samples of the samples to which soy protein powder was added, it was determined that the drying rates increased with the increase in the additive rate and varied between 0.422-0.744 g moisture/g drying agent.minute. It was found that the osmotic effect of soy protein was more dominant than the NaCl carrier agent, thus causing an increase in the rate of moisture removal.

3.2 Mathematical Modeling

The findings of the experimental mathematical models of onion powder samples are given in Table 1.

Table 1. Data of mathematical models.

Models	Carrier agent (%)	k	h	j	m	p	R^2
Lewis	Control	0.1135	-	-	-	<0.0001	0.9440
	% 10	0.1071	-	-	-	<0.0001	0.9591
	% 20	0.0806				<0.0001	0.9643
	% 30	0.0851	-	-	-	<0.0001	0.9616
Jena Das	Control	1.0461	0.4655	0.6845	0.0419	<0.0001	0.9539
	% 10	1.0397	0.4614	0.6927	0.0356	<0.0001	0.9667
	% 20	1.0313	0.4467	0.7220	0.0263	<0.0001	0.9700
	% 30	1.0310	0.4490	0.7174	0.0264	<0.0001	0.9669
Wang Singh	Control	-0.0788	0.0014	-	-	<0.0001	0.9918
	% 10	-0.0755	0.0014	-	-	<0.0001	0.9968
	% 20	-0.0571	0.0007				0.9982
	% 30	-0.0609	0.0009	-	-	<0.0001	0.9957

It has been seen that the drying models of the onion powder samples produced by drying according to Table 1 are reliable. In the study, Lewis model estimated the experimental moisture content of onion powder samples best (R^2: 0.9643) in the samples with 20% NaCl added. The Jena-Das model estimated the experimental moisture content values best (R^2: 0.9700) in samples with 20% NaCl added. The Wang-Sing model, on the other hand, estimated the moisture content values best (R^2: 0.9982) in the samples to which 20% NaCl was added. Among all models, the Wang-Sing model best predicted the experimental moisture content of onion powder.

3.3 Effective Moisture Diffusion

The determined effective moisture diffusion values are given in Table 2.

Table 2. Effective diffusion values of onion powder samples.

Carrier agent (%)	Effective moisture diffusion (m^2 s^{-1})
C Control (0%)	2.86×10^{-6}
% 10	1.77×10^{-6}
% 20	1.22×10^{-6}
% 30	9.97×10^{-7}

According to Table 2, it was found that there was an inverse relationship between the carrier agent ratio and effective moisture diffusion values. It is thought that the high carrier agent ratio is effective in making it difficult for moisture to escape from the product. Kumar et al. [32] dried onion slices at 50, 60, and 70 ºC. They examined the effect of immersing the samples in 0.1%, 0.3%, and 0.5% potassium sulfate solutions before drying. They found that drying temperature and pretreatments affected the effective moisture diffusion values. They found that effective moisture diffusion values varied between 1.33 - 2.49 × 10^{-8} m^2 s^{-1}.

3.4 Color Values

The color values of the onion powders are given in Table 3.

Table 3. Color values of samples.

Carrier agent rate	*L*	*a*	*b*	*C*	*ΔE*
Fresh	74.85±2.58ab	-1.41±0.35b	11.90±0.95c	24.06±.0.99a	-
Control	78.09±0.65a	-2.45±1.32b	18.50±1.73b	12.01±1.66c	8.68±2.77c
10%	88.23±0.43cd	2.41±0.27a	26.60±0.55a	26.71±0.57a	21.50±2.69b
20%	986.31±0.52a	-1.49±0.94b	18.11±2.62b	18.19±2.61b	24.19±2.85ab
30%	98.05±0.76a	2.16±1.17a	19.04±3.21b	19.22±2.98b	26.40±3.73a

Photos of the produced onion powders are given in Figure 2.

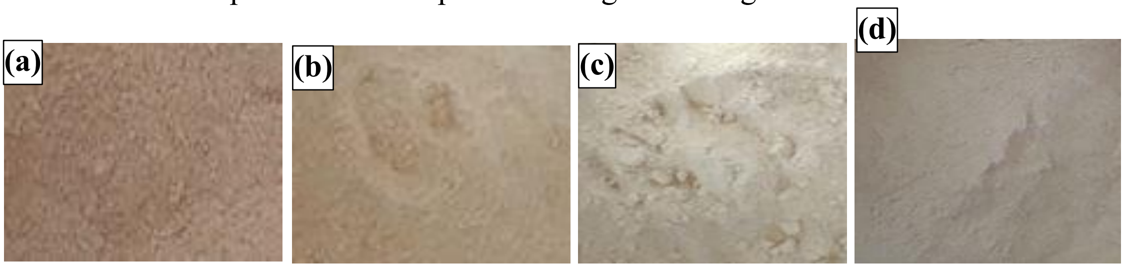

Figure 2. (a) 0%; (b) 10%; (c) 20%; (d) 30%.

It has been determined that onion powders with control and carrier agents added could not preserve the brightness and yellowness values of fresh onion puree. The reason for this is thought to be that the brightness value and yellow color pigments of onion puree are sensitive to heat and darkening and pigment fragmentation occur at a high rate with heat. This event caused the brightness and yellowness values to change. It was found that there is a statistically significant ($p<0.05$) difference between the brightness value of the onion samples dried in microwave-freeze, hot air, and vacuum-freeze methods and the fresh ones in a study by Wang et al. [33]. In another study by Maftoonazad et al [34], it was determined that the yellowness value of the onion slices dried in the microwave-assisted convective oven increased according to the fresh one significantly ($p<0.05$). The brightness value of fresh onions was significantly affected by the drying methods. It was found that the red color pigments of the onion puree were in the drying processes after control and the addition of a 20% carrier agent. No significant difference was found between the chroma color values of the samples with onion puree and 10% carrier substance added. It has been observed that the production of onion powder by adding a 10% carrier agent protects the color saturation (chroma) of the puree better. This shows that the carrier agent used at the rate of 10% does not prolong the drying time too much compared to the control samples and has a protective effect on the color pigments (*a*, *b*) of the puree against heat. The color pigments of the control samples were exposed to heat for a shorter time compared to onion powders with 10% carrier agent- added, but since no carrier agent can protect the color pigments against heat, the chroma values of the control samples were found to be lower. In the control samples, the total color change occurred less statistically ($p<0.05$). When the control and 10% powder sample groups were compared in terms of total color change, the control group preserved the brightness (*L*) value of the puree statistically ($p<0.05$) better, causing the total color change value to be calculated lower.

3.5 SMER and SEC Values

SMER and SEC kinetics of the drying processes are given in Figure 3.

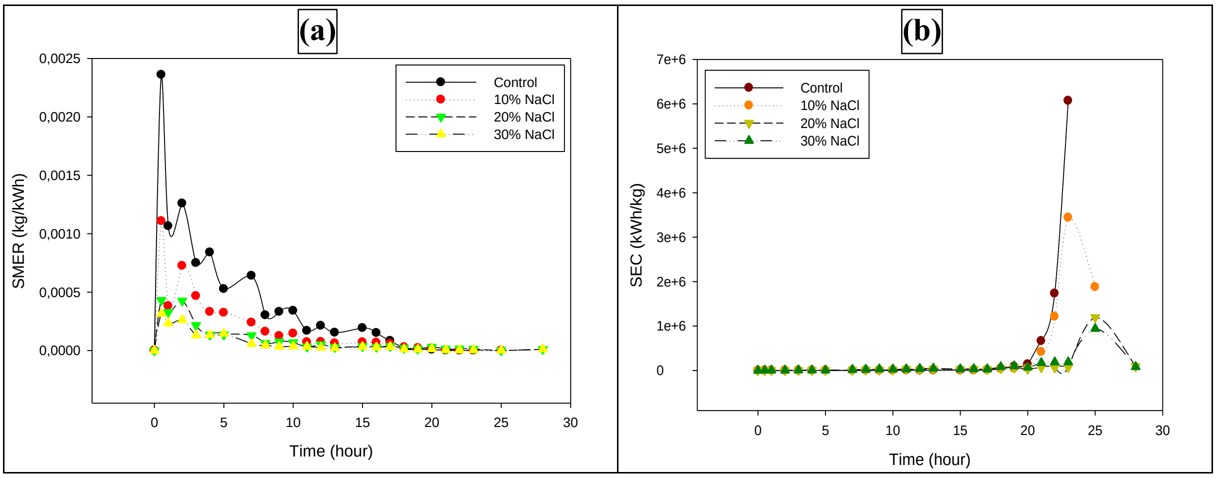

Figure 3. (a) SMER values; (b) SEC values.

According to Figure 3, it was observed that the *SMER* values of the dried onion powder samples increased rapidly after the first half hour. It is thought that the reason for this is that the oven temperature in the first half hour is spent on heating the product. It was found that *SEC* values increased further in the following hours. This situation is caused by the decrease in the amount of moisture that disappears with drying. It was determined that the lowest energy consumption value was in the control samples. Wang et al. [33] reported that onion slices were ground into powder by different methods. It was determined that the average *SEC* values of drying processes varied between $7 - 9 \times 10^5$ kJ/kg. It was observed that the values stated in the literature and the *SEC* values of the control samples obtained within the scope of this study were compatible with each other. The reason why the *SEC* value in the literature study was lower than the value obtained in this study was due to the low drying temperature (45 ºC).

3.6 Evaporation Energy

The kinetics of steam energies of drying processes are given in Figure 4.

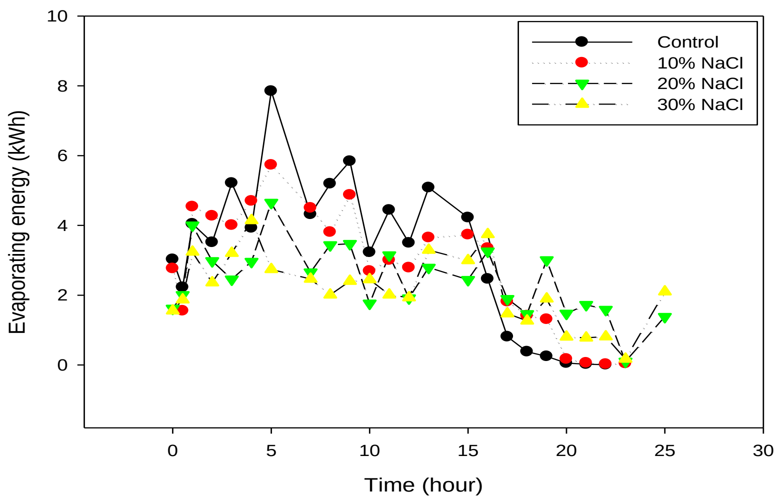

Figure 4. Evaporation energy.

It has been observed that NaCl affected steam energy values. The reason for this is that as the moisture moving away from the sample decreased, the vapor energy also decreased. The average steam energy values determined for 0% (control), 10, 20, and 30 samples were determined as 3.16, 2.82, 2.43, and 2.15 kWh, respectively. The increase in the carrier material ratio used to ensure texelization reduced the average steam energy. The reason for this is the same as the results obtained in effective moisture diffusion and drying rates. Rabha et al. [35] calculated the average steam energy in their pepper drying study at 50 ºC in a convective dryer. The steam energy value stated in the literature was found to be slightly lower than the steam energy value obtained in this study. This is due to the low drying temperature value and the different physical properties (moisture, microstructure, physicochemical) of the products. It was observed that the data obtained in the literature and the findings obtained within the scope of the study were compatible.

3.7 Physical and Flow Properties of Onion Powder

The determined properties of the powders are given in Table 4.

Table 4. Physical and flow properties.

Carrier agent (%)	Process efficiency (%)	Tapped density (g/ml)	Bulk density (g/ml)	Carr (%)	Hausner	Dry matter (%)	Moisture content (d.b.)
Kontrol	99.50	1.16±0.023b	1.09±0.047b	6.69±5.94ab	1.07±0.067ab	10.32±0.067	0.05
10%	99.87	1.28±0.020b	1.23±0.064a	4.03±3.72b	1.04±0.040b	19.32±0.433	2.33
20%	99.89	1.23±0.024c	1.13±0.015b	8.12±2.72ab	1.09±0.032ab	28.32±0.071	5.40
30%	99.75	1.42±0.014a	1.24±0.025a	12.17±1.39a	1.14±0.018a	37.32±0.047	0.28

It has been observed that NaCl affected the physical and fluidity properties of onion powders. Compared to the control group, the bulk density parameters of onion powders dried by adding a carrier agent increased. In this case, it is thought that the NaCl substance affects increasing the volume densities by reducing the porosity rate in onion powder. No significant difference was found in terms of compressed density values between the control and 10% NaCl added samples ($p>0.05$). There was no significant difference ($p>0.05$) between the control group and the powder group with 20% carrier agent added in terms of bulk density. It has been determined that the pourability (*CI*) index value of all powder groups produced is in the “Very Good” group. Carrier agent significantly ($p<0.05$) affected the *CI* index of onion powder. It was determined that the group with the best *CI* index statistically was onion powders with 10% carrier agent added. It has been determined that if the carrier agent ratio added to the onion puree is more than 10%, it worsens the pourability statistically. This situation caused the sugar particles in the structure of the product to be transported to the surface and caramelized with heat, together with the increase in the added NaCl ratio. It is thought that this event increases the stickiness of the powder and reduces the pourability (*CI*) index. It has been determined that all onion powders produced are in the "A" category in terms of the Hausner index, which is the stickiness value. Carrier agent had a significant ($p<0.05$) effect on the Hausner index (*HR*) of onion powders except for the 20% group. The reason why there is no significant difference between the control group and the group with 20% carrier agent added is thought to be due to the closeness of the degree of adhesion and encapsulation effect, which is increased by the effect of NaCl. It is thought that this event did not have a dominant effect on the Hausner index and caused it to be included in the statistical group similar to the control group. The increase in the carrier agent ratios caused the Hausner index of the onion powder produced to increase statistically. The reason for this is that with the effect of osmotic drying, the sugar particles in the product are carried to the surface and caramelized with the heat. Onion powder groups produced by adding carrier agents were found to have a higher dry matter ratio than the control group. It is thought that NaCl increases the resistance of the onion puree structure and reduces the dry matter breakdown that may occur with heat. When examined in terms of humidity, 20% onion powder made it difficult to remove moisture during drying. It is thought that the carrier agent added at the rates of 10% and 20% creates a barrier to the removal of the underlying moisture, making it difficult to dry and causing the humidity to remain at higher levels. However, it is thought that the osmotic drying effect of the carrier agent, which is added by 30%, is more dominant than the barrier effect which creates moisture removal. This allowed the moisture content of the powder to reach lower levels. Michalska-Ciechanowska [9] produced cranberry powder by a freeze-drying method using maltodextrin and inulin carrier agents. They used 15%, 25%, and 35% carrier agents in food powder production. As the use of carrier agents increased, the moisture content of the powder decreased. It was found that maltodextrin did not have a significant ($p>0.05$) effect in terms of density property. For inulin, they found that the density increased at a statistically significant level. Gawalek and Domain [36] produced dextrin carrier agents from potato and tapioca products. The increase in tapioca dextrin rate, decreased the tapped density rate of powder. They found that there was a significant decrease in bulk density ratios with increasing potato dextrin ratio ($p<0.05$). This was due to the different specific gravity of the dextrins used. They found that for both dextrins (potato and tapioca), the Hausner index of aronia powder was in the “A” and “C” categories. These values indicate that the stickiness is at low and medium levels, respectively. They reported that the increase in the rates of both carrier agents used reduced the Hausner index of the produced aronia powder. The wettability properties of onion powders are given in Figure 5.

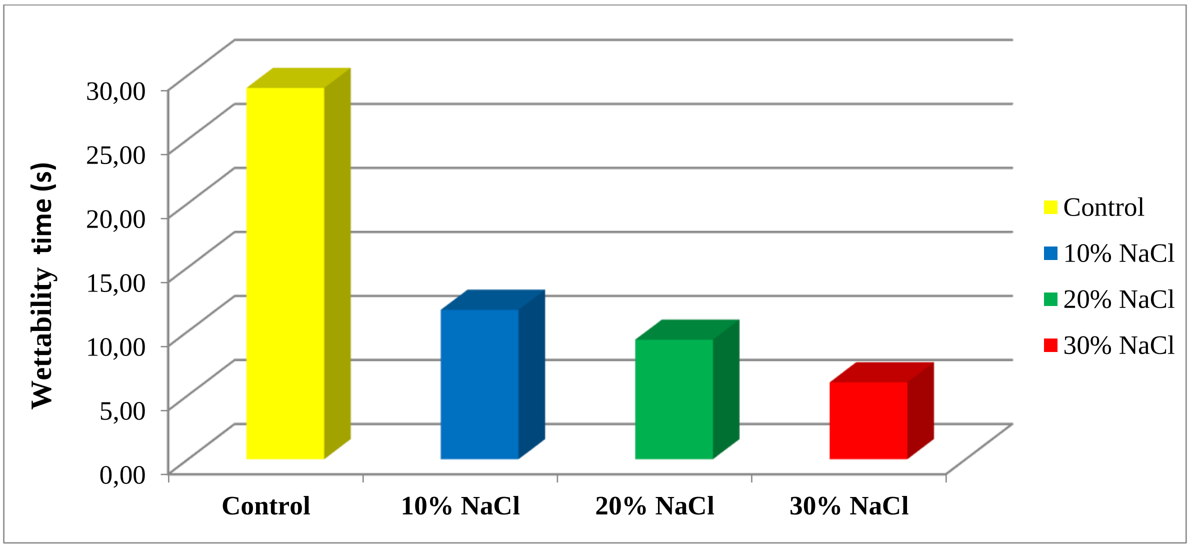

Figure 5. Wettability time of onion powders.

According to Figure 5, it has been observed that the NaCl affected the wettability of onion powder. It has been determined that increasing the NaCl ratio used increases the wetting ability of onion powder. This is thought to be due to the shorter soaking time of the NaCl agent in water. It was determined that the NaCl agent used in this event contributed positively to the wetting ability of onion powder. The mean wetting times for control, 10, 20, and 30% NaCl agent added onion powders were determined as 29±2.00, 11.67±2.52, 9.33±1.53 and 6±1.00 seconds, respectively. Gopinathan et al. [37], determined the average wetting time of the çempedak fruit powder produced by drying at 55 ºC in a convective dryer as 10.56 seconds. Aparna et al. (2021) determined the wetting times of onion powders produced by the sun (45 ºC), tray (50 - 55 ºC), vacuum (50 - 55 ºC), and freeze-drying methods as 42, 39, 36, and 30 seconds, respectively.

4 CONCLUSION AND SUGGESTIONS

The effect of the NaCl on the physicochemical and energy consumption values of the samples was significant. It was observed that the increase in the carrier substance ratio has a negative effect on the moisture and drying rates of the samples. It has been observed that the carrier agent reduced the effective moisture diffusion value and increased energy consumption because it created a barrier on the samples. The best color properties were determined when a 10% carrier agent was used. It has been observed that when the carrier agent was used above 10%, the color properties of the fresh product could not be preserved. It has been observed that the carrier agents and ratios used contributed positively to the compressed bulk density and wettability of onion powders. It was concluded that the carrier agent increased the *CI* and *HR* index values of the produced onion powders, that is, negatively affected them. It is thought that this situation is due to the high ratios chosen for the carrier agent. The NaCl used in the study negatively affected the drying kinetics, energy consumption, flowability, and adhesion indices of the carrier agent. It has been observed that it positively affected bulk densities and wetting time. It is recommended to investigate the effect of lower rates of NaCl carrier agent used in onion powder in the next study.

Statement of Research and Publication Ethics

The study is complied with research and publication ethics.

Artificial Intelligence (AI) Contribution Statement

This manuscript was entirely written, edited, analyzed, and prepared without the assistance of any artificial intelligence (AI) tools. All content, including text, data analysis, and figures, was solely generated by the authors.

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