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Stabilization and Optimization of Doogh Powder Using Some Hydrocolloids: Production and Characterization

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ABSTRACT

Doogh, a favorite acidic dairy drink, usually suffers from low stability and swelling due to microbial activation, protein aggregation and, consequently, phase separation, which happens at low pH. In this study, optimization of doogh powder production stabilized by pectin and tragacanth was performed using response surface methodology for selection of appropriate hydrocolloid and processing condition. The results showed that the quality of doogh powder strongly depended upon the spray drying temperature and type of hydrocolloid addition. Optimum operating conditions were found to be an inlet air temperature of 122ºC and stabilization using tragacanth, under which moisture content, bulk density, solubility, Carr index, serum separation, color (L), pH, Hausner ratio, and porosity were 5% (wet basis), 0.31 g cm^{-3}, 88%, 37, 65%, 89, 4.33, 1.59 and 73.5%, respectively. Evaluation of sensory attributes (color, odor, flavor, consistency, and total acceptance) confirmed that there was no significant difference (P> 0.05) between dried doogh powder produced in optimized conditions and freshly prepared sample.

Keywords: Pectin; Response surface methodology; Spray drying; Tragacanth.

INTRODUCTION

Milk and its derivatives have enormous beneficial health effects and can fulfill the vital nutritional needs of the human diet (Davoodi *et al.*, 2013). This valuable foodstuff is one of the most important sources of approximately all nutrients such as protein, minerals, vitamins, fatty acids, and sugars (De Marchi *et al*, 2018). Fermented dairy products have become more popular than raw materials due to their nutritional properties and extended shelf life (Jay, 1995; Mena-Sanchez *et al*, 2018). Doogh is a fermented drink derived from lactic acid fermentation of milk, which is produced from yogurt (after fermentation) or milk (before fermentation) and is known as Ayran in Turkey and Lassi in India. It is traditionally produced in the Middle East, but also consumed in Armenia, Azerbaijan, and Balkans (Azarikia and Abbasi, 2010; Kiani *et al*, 2010). Having vitamins and nutrients similar to milk, easier calcium absorption in the body and better digestion are the merits of doogh rather than milk (Joudaki, Mousavi, Safari, Razavi, Emam-Djomeh, and Gharibzahedi, 2013a, 2013b). The physical stability and shelf life of this healthy drink are directly related to some microbial and chemical factors. Firstly, physical instability of doogh and phase separation is one of the major chemical phenomenon caused by low pH and salt (Azarikia and Abbasi, 2010; Joudaki *et al.*, 2013a). Secondly, due to the presence of microorganisms like Lactic acid bacteria, yeasts, and fungi in dairy products, these products must be kept at a cool place to reduce their activity (Choi and Kosikowski, 1985), which increases production costs. The latest drawback can be overcome by the development of dried dairy products.

Drying is considered as a complicated

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preservation technology for solid, liquid, and foam-liked foods (Reale *et al.*, 2019). Spray drying is one of the most cost-efficient methods that can produce a dry powder with appropriate properties. Additionally, because of less heat contact time and considerable quality of the final product, it is widely used in the food and pharmaceutical industry. Dried products have some advantages over their liquid forms such as longer shelf life, less volume or weight, lower transportation cost, and higher storage capacity (Erbay *et al.*, 2015; Fazaeli *et al*., 2012; Koc *et al.*, 2014; Teijeiro *et al.*, 2018; Telfser and Gómez Galindo, 2019).

Hydrocolloids, due to the multi-functional roles including stabilizing, thickening, and emulsifying abilities, are used in food manufacturing. Pectin and tragacanth are known as the two important hydrocolloids used in the food industry (Azarikia and Abbasi, 2010; Joudaki *et al.*, 2013a). Pectin is an anionic polysaccharide consisting of partly methyl-esterified galacturonic acid in connection with arabinose, galactose, and xylose. This polysaccharide is able to stabilize acidified dairy beverages, milky fruit juices, and drinkable yogurts (Joudaki *et al.*, 2013b). Gum tragacanth consists of two fractions (water-soluble and water-insoluble) and is used as a stabilizer, emulsifier, and thickener in food industries (Azarikia and Abbasi, 2010).

There are some reports on the production of acidified milk drinks powder. According to Mohammadifar *et al*. (2007), polysaccharides can prevent serum separation in acidified milk drinks. Furthermore, Azarikia *et al*. (2010) concluded that the stability and viscosity of doogh will be increased by adding tragacanth in doogh formulation (Azarikia and Abbasi, 2010). Kiani *et al*. (2010) investigated the effect of gellan and in combination with high-methoxyl pectin on the structure and stability of doogh (Kiani *et al*., 2010). Teimouri *et al*. (2018) worked on the stabilization mechanism of various types of inulin with a combination of other hydrocolloids on milk-sour cherry juice. Joudaki *et al*. (2013) investigated the effect of two commercial pectins (amidated pectin and grapefruit-seed extract pectin) on doogh stability and evaluated its physicochemical properties (Joudaki *et al.*, 2013b).

Response Surface Methodology (RSM) is basically a mixture of mathematical and statistical methods used for optimizing and developing experiments by considering the interactions of the variables. The major goals of using RSM are to obtain the optimized condition of the process and explore the effect of various independent variables on the responses with the minimum number of experiments (Karimifard and Alavi Moghaddam, 2018; Ruby Figueroa *et al*., 2011).

There is limited data on the optimization of doogh powder properties and its physical characteristics. Therefore, this study aimed to optimize doogh powder production using spray drying based on RSM. Also, the effects of drying temperature and application of high methoxyl pectin and tragacanth on the physicochemical properties of doogh were investigated.

MATERIALS AND METHODS

Materials

Fresh skim milk was acquired from the Pegah Dairy Co. (Isfahan, Iran; 90.4% moisture, 9.6% total solid, 3.6% protein, 4.9% carbohydrate, 0.2% fat, and 0.9% ash contents; all based on wet basis). The starter culture (YF-3331, containing *Streptococcus thermophilus* and *Lactobacillus delbrueckii* ssp. *bulgaricus*) was provided by Hansen Co. (Chr. Hansen, Denmark). Maltodextrin DE 18-20 was purchased from Pooran Powder Sepahan Co. (Iran, Isfahan). High-methoxyl pectin, sodium chloride, and petroleum ether were bought from Merck (Darmstadt, Germany). Tragacanth gum was provided from the local market (Isfahan, Iran).

Doogh Preparation

The skim milk that was already pasteurized (at 72ºC) was heated from room temperature to 45 ºC, inoculated with a commercial starter culture, and incubated at 45ºC for 4 hours. Based on preliminary tests, the resulting yogurt was diluted with the proportion of 60% yogurt, 34.3% drinkable water, 5% maltodextrin, and 0.7% salt. As the produced yogurt was used for spray drying, the proportion of yogurt was considered higher than usual to obtain more total solid. First, maltodextrin with a certain amount of drinkable water was added to the yogurt and stirred until a uniform mixture was obtained. Afterward, the salt was added and the mixture was kept in the refrigerator for the final fermentation process (5°C for 24 hours). Pectin and tragacanth were gradually dispersed into the known amount of cold water and dissolved to prevent agglomeration, and added to the doogh formulation. Therefore, doogh fermentation occurred in the presence of hydrocolloids. Doogh powders were produced by a mini spray dryer in a pilot-scale at 100-140°C (Dorsa Behsaz, Iran) under conditions that are tabulated in Table 1. The samples were kept into an isolated container for further experiments (Kiani *et al.*, 2010).

Analytical Methods

Moisture Content and pH

moisture content was determined by weighted about 1 gram of doogh powder in a plate and put into the oven (Memmert, Germany) at 102±2°C for 2 hours (Koc *et al.*, 2014). To evaluate pH value, one g of doogh powder was dissolved in 10 mL distilled water. The pH of the suspension was measured by a pH measuring instrument (Jenway 3330, US) (Banavara *et al.*, 2003).

Bulk, tapped bulk and particle densities

For this purpose, the cylinder with known Volume (V_1) was Weighed (W_1) and filled up with the powder (W_2) until the marked line. The bulk density was calculated as (A/S Niro Atomizer, 1978):

$$\text{Bulk density } (\rho_{bulk}): \frac{W2-W1}{V1} \quad (1)$$

To measure the tapped bulk density, the cylinder was tapped 100 times vigorously:

$$\text{Tapped bulk density } (\rho_{tapped\ bulk}): \frac{W2-W1}{V1} \quad (2)$$

To determine the particle density, doogh powder (one g) was poured in a measuring cylinder containing petroleum ether (5 mL) and shaken until all the particles were suspended into the suspension. The powders on the wall were eliminated by 1 mL surplus petroleum ether. The total Volume of petroleum ether and suspended powder (V) was measured by reading volume from degrees of measuring cylinder and particle density (mg L^{-1}) was calculated as (A/S Niro Atomizer, 1978):

$$\text{Particle density } (\rho_{particle}): \frac{m}{V-6} \quad (3)$$

Porosity

The porosity was calculated by the correlation between bulk and tapped bulk densities (Sahin and Sumnu, 2007):

Table 1. Operation conditions for spray drying.

Parameter	Quantity
Feed rate	3 mL min^{-1}
Hot air flow rate	30 m^3 h^{-1}
Feed temperature	25°C
Open time of nozzle in each spray cycle	3 s
Close time of nozzle in each spray cycle	0.5 s
Nozzle air pressure	3 bar

Porosity (ε): $\frac{\rho\ \text{particle} - \rho\ \text{tapped}}{\rho\ \text{particle}} \times 100$ (4)

Flowability and Cohesiveness

The Carr Index (CI) and Hausner Ratio (HR) were utilized for evaluating the flowability and cohesiveness of powders, respectively. As shown in Equations (5) and (6), both bulk and tapped densities are important factors in calculating CI and HR:

CI: $\frac{\rho\ \text{tapped} - \rho\ \text{bulk}}{\rho\ \text{tapped}} \times 100$ (5)

HR: $\frac{\rho\ \text{tapped}}{\rho\ \text{bulk}}$ (6)

As shown in Table 2, powders' flowability and cohesiveness were categorized based on their CI and HR values (Sahin and Sumnu, 2007).

Solubility

The solubility index of doogh powder was determined following the method of Eastman *et al*. (1984). Doogh powder (0.5 g) was carefully weighed and gradually added into the centrifuge tube and 50 mL of distilled water was added and carefully mixed for 5 min. Then, the suspension was centrifuged (Hermel, Germany) at 3,100 rpm for 15 minutes. Consequently, 25 mL of supernatant was transferred to the evaporating dish and dried at 110ºC for 4 hours. The solubility of powder was calculated as (G_1: Amount of total solid in supernatant and G_2: Weight of initial doogh powder) (Eastman *et al*., 1984):

Solubility: $\frac{G\ 1\times 2}{G\ 2} \times 100$ (7)

Table 2. Flowability and cohesiveness powder categorization in terms of CI (Carr Index) and HR (Hausner Ratio), respectively.

% CI (Carr index)	Flowability
< 15	Very good
15-20	Good
20-35	Fair
35-45	Bad
> 45	Very bad
HR (Hausner Ratio)	Cohesiveness
< 1.2	Low
1.2-1.4	Intermediate
> 1.4	High

Color Measurement

The Lightness (L*) of powder was assessed using a color meter (Color meter, ZE6000, Hunterlab, Nippon, Japan). Firstly, the instrument was calibrated and then the sample was put in the specific cell and the L* value was measured (Banavara *et al.*, 2003).

Serum separation

In order to analyze stability, a certain amount of reconstituted doogh was made from powder and held into the cylindrical tubes (10 mL) for 15 days at 4.0±0.1°C. As each phase could be easily detected visually, the height of sedimentation (h) and whole volume (H) were measured by Caliper and serum separation was calculated as following (Joudaki *et al.*, 2013b):

Serum Separation (SS): $\frac{h}{H} \times 100$ (9)

Sensory Evaluation

Sensory evaluation of doogh including taste, color, consistency, aroma, and overall acceptability were analyzed using a hedonic test (7-point structured scale; one for least appropriate and seven for most appropriate). For this purpose, two samples including modified doogh powder and commercial doogh (Peghah Co. as a control sample), were randomly encoded by three-digit numbers and presented to the panelist group who were chosen from Graduated Students or Staffs of the Department of Food Science and Technology.

Response Surface Methodology

The present study was conducted to analyze the effect of various factors and

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optimize the doogh formulation by the Response Surface Methodology (RSM). It should be noted that the obtained results were made in triplicate and analyzed using Design Expert Software (version 7.0) by D-optimal design. Table 3 shows the designed treatments.

Analysis of variance was performed using SPSS software (version 12.0; Chicago, IL) by complete randomized design or randomized block design (for sensory data). Means were compared using the least significant test (LSD, P< 0.05).

RESULTS AND DISCUSSION

Doogh powders were prepared according to the conditions presented in Table 3, and physicochemical properties were evaluated.

Moisture Content

The moisture content signifies the amount of water in the total weight of powder and checked in order to assess the quality of doogh powder during the storage. This feature significantly affects other physicochemical characteristics of the powder. For longer shelf life and less microorganisms growth, a suitable range of water content is 4-5% (Koç *et al.*, 2010).

(Figure 1-a) shows the moisture content of doogh powder as the functions of inlet air temperature and gum type that varied from 4.4 to 6%. Clearly, higher temperature reduced the moisture content of samples containing tragacanth and control (P< 0.05), while it had no significant effect on pectin treated samples (P> 0.05). Furthermore, TG100 and PG100 had the highest water content while GF130 had the lowest amount. Overall, temperature affects wettability considerably (P≤ 0.05), which is attributed to the fact that at higher inlet air temperature, the heat rate transferred to the water particles was greater and, therefore, more energy provides for water evaporation. Moisture content values were in accordance with previous researches and were low enough to protect the dried powders against chemical and microbial deteriorations (Fazaeli *et al*., 2012; Koc *et al*,, 2010).

Bulk Density

Bulk density is considered as a major

Table 3. Designed treatments by response surface methodology.

Number	Variable 1 (Inlet air temperature ºC)	Variable 2 (Gum)	Abbreviation
1	140	Tragacanth	TG140
2	140	Pectin	PG140
3	100	Tragacanth	TG100
4	100	Tragacanth	TG100
5	100	Without Gum	GF100
6	140	Without Gum	GF140
7	100	Pectin	PG100
8	140	Pectin	PG140
9	120	Pectin	PG120
10	130	Tragacanth	TG130
11	100	Pectin	PG100
12	100	Without Gum	GF100
13	120	Without Gum	GF120
14	130	Without Gum	GF130
15	110	Tragacanth	TG110
16	140	Tragacanth	TG140
17	120	Tragacanth	TG120

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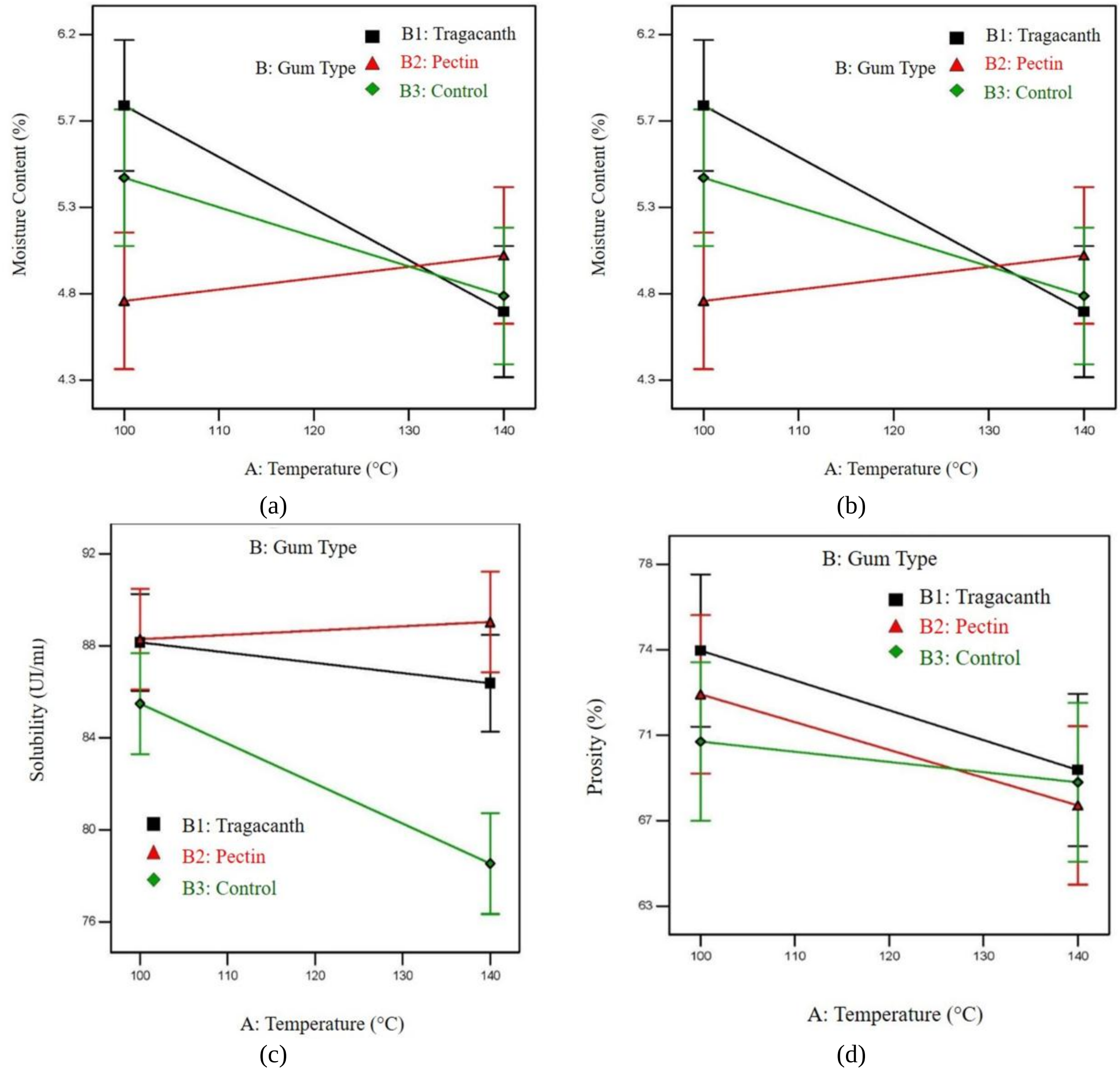

Figure 1. Effect of drying temperature and type of hydrocolloids (a) on moisture content of doogh powder, (b) on bulk density of doogh powder, (c) on solubility of doogh powder and (d) on porosity of doogh powder.

property of powders in product acceptance and depends upon the particle size and geometry, moisture, and chemical composition (Ganesan *et al*., 2008). This value is well related to porosity, fat content, and storage stability of powder (Erbay *et al.*, 2015; Koc *et al.*, 2014). The bulk densities of doogh powder were in the range of 0.23-0.36 g/cm^3 (Figure 1-b) and the lowest bulk density was found for TG130 while PG140 showed the highest value.

Goula and Adamopoulos (2010) and Walton (2000) revealed that increasing the inlet air temperature led to a reduction of bulk density in orange juice, due to faster evaporation rate and consequently the formation of the porous structure. Generally, higher moisture leads to the production of bulker powder (Goula and Adamopoulos, 2010; Walton, 2000). The analysis of variance showed that temperature had no significant effect ($P > 0.5$) on bulk density, probably because of the limited applied temperature range (100-140ºC). On the other hand, gum treatment had a noticeable effect on bulk density ($P < 0.01$). Samples containing pectin in comparison with tragacanth and gum free treatments had higher bulk density (Figure 1-b). It is reported that the nature of hydrocolloids and electrostatic bonds influence the bulk density. In this regard, lower bulk density in samples containing tragacanth compared to pectin samples could be due to the more hydrophilic nature of tragacanth, and, therefore, less water evaporation (Ganesan *et al.*, 2008).

Solubility

Solubility is an important factor for the reconstitution of doogh powder and quality determination. This feature, directly and indirectly, is affected by some factors such as the amount of acid lactic that leads to casein aggregation, heat treatment that causes casein denaturation, and eventually the number of stages in the drying process (Koc *et al.*, 2014; Straatsma *et al.*, 1999). The solubility values of doogh samples were varied from 78.3 to 90.4% and the minimum and maximum were attributed to GF120 and PG100, respectively. According to (Figure 1-c), increasing temperature led to a reduction of the solubility of the control and the sample containing tragacanth ($P< 0.05$). However, there was no significant correlation between temperature and solubility for the pectin treated sample ($P> 0.05$). Forming a thick layer on the surface of particles at high temperature caused a decrease in molecular diffusion and, consequently, solubility of powders (Fazaeli *et al.*, 2012). On the other hand, the solubility of the samples containing hydrocolloids was much higher than the control, which could be related to the protective effect of hydrocolloids on casein against heat and denaturation. Furthermore, the hydrophilic nature of gums and gel formation tendency caused higher solubility (Azarikia and Abbasi, 2010; Rennie *et al.*, 1999).

Porosity

Factors such as pasteurization temperature and preheating before drying, feed rate, amount of air confined between particles, foam formation, and drying conditions can influence the porosity. This feature, indirectly, is related to the particle size and signifies the amount of air confined between particles, which is related to the particle morphology, particle size, and degree of powder agglomeration (Patel *et al.*, 2009). If the powder contains uniform particle size, the space between them would decrease and, consequently, porosity would increase. According to (Figure 1-d), the porosity values of the samples were between 63.3 to 75.8% and the lowest and highest amounts were for TG140 and TG100, respectively. It should be noted that the porosity range of samples was in the range that is considered as the high porosity powders. Koc *et al.* (2010), stated that the porosity of yogurt powder was really fair as 36% (Koc *et al.*, 2010). The analysis of variance showed that none of the variables (gum, temperature, and their interaction) had a significant effect on porosity ($P< 0.05$).

Flowability

Flowability is defined as solids or powder's tendency to flow. This property depends on various physical characteristics such as particle size and size distribution (larger size and higher uniformity lead to more flowability) (Walton, 2000). Primary knowledge about this property is important because of devising powder's storage equipment, environmental conditions, and the procedure (Ganesan *et al.*, 2008; Saw *et al.*, 2015).

The flowability of spray dried doogh powders was between 29 and 40%, which varied from bad to almost-good according to Carr index and its categorization (Table 2). With increasing temperature, the Carr indexes of tragacanth and pectin treated samples were almost constant; while it decreased for the control sample ($P< 0.05$). The type of hydrocolloids did not have a significant effect on the flowability of powders ($P> 0.05$) (Figure 2-a). Other

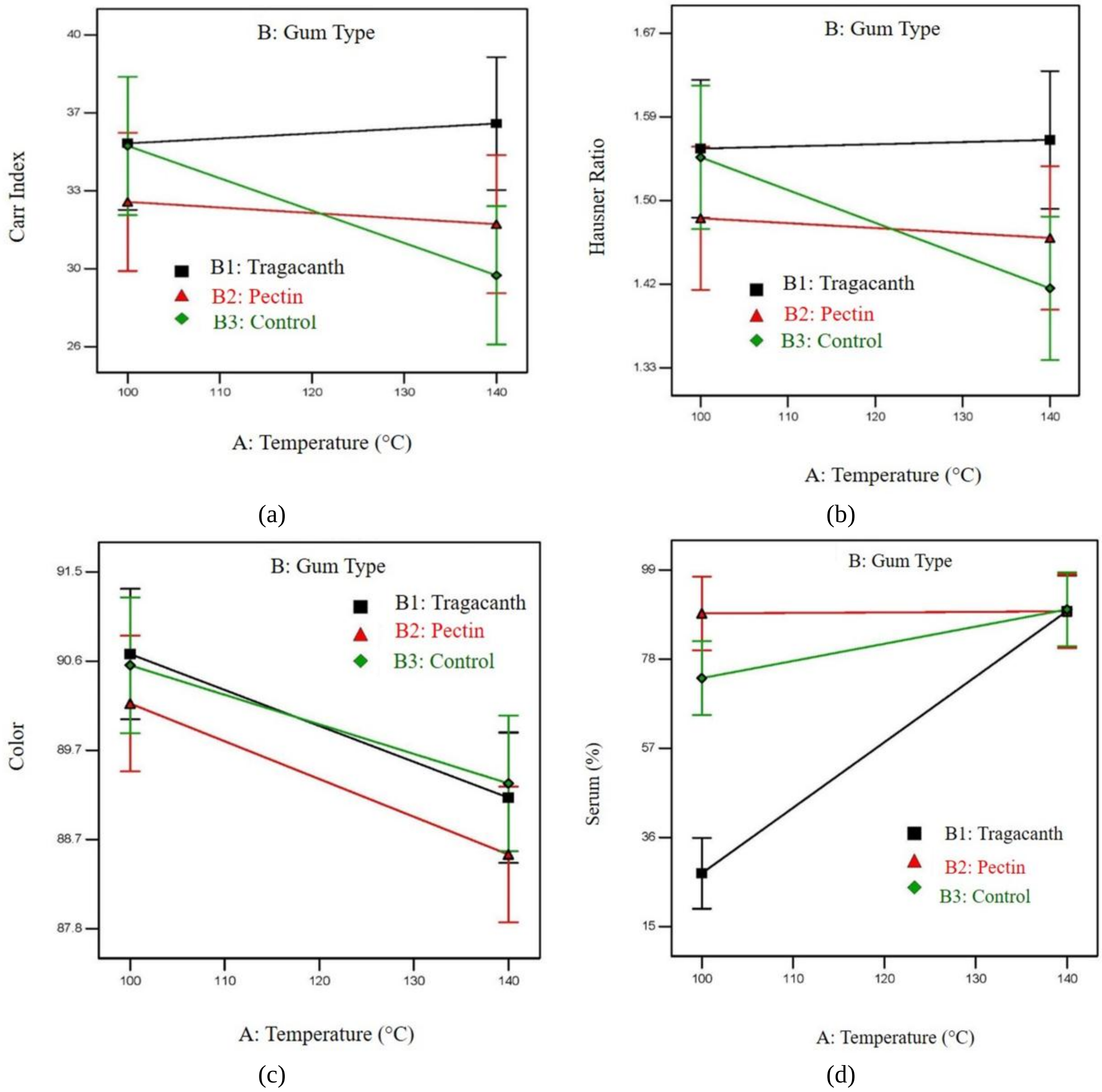

Figure 2. Effect of drying temperature and type of hydrocolloids (a) on Carr index of doogh powder, (b) Hausner ratio of doogh powder, (c) on lightness of doogh powder (d) on serum of doogh powder.

investigations showed that yogurt powders had moderate-poor flowability (CI= 27.93%) with small particle size (3.053 µm) (Koc *et al.*, 2014).

Cohesiveness

Cohesiveness is specified as particle adhering to each other and is a kind of intrinsic property that is directly related to the intermolecular force (Ganesan *et al.*, 2008). In this experiment, the Hausner Ratio (HR) of samples was between 1.41 and 1.61, and based on its classification shown in Table 2, all samples were considered as high-cohesive. (Figure 2-b) illustrates the effect of drying temperature and type of hydrocolloids. There was no evident effect on Hausner value and, consequently, on cohesion (P> 0.05).

High cohesiveness of doogh powder and low flowability could be the result of high atomization pressure in order to obtain lower

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water content and also prohibit doogh protein coagulation that might lead to nozzles blockage. Although this fact caused a reduction in particle size as well as better water evaporation, while it led to producing cohesive powder. (Jinapong *et al*., 2008). Rennie *et al.* (1999) revealed that by decrease in particle size of milk powder from 200 to 80 nm, the cohesion increased significantly. Besides, they indicated that higher cohesion value was attributed to the higher moisture content that is probably justified by more liquid bridge formation (Rennie *et al*., 1999).

Lightness

Color is a critical characteristic of powder due to the fact that powder's appearance is the first and essential factor in the quality assessment, which is significantly affected by some factors such as the primary color of sample and quality of drying condition. Maillard reaction during drying leads to a decrease in lightness. Lightness in colorimeter is considered as a brightness indicator and is used for comparison of the samples (Banavara *et al.*, 2003). Increasing of temperature led to a reduction of lightness (Figure 2-c). It is reported that inlet air temperature is directly related to outlet powder's temperature, hence, under high temperature in the initial stage, Maillard reaction occurred and, finally, L value decreased (Koc *et al.*, 2010).

pH

pH is determined as an indicator for monitoring of microbial viability after drying. Low pH of doogh solution after reconstitution and keeping in adequate time is attributed to higher microorganism viability during drying. The results showed that, under the operation conditions, the pH

values were in the range of 4.32 to 4.35 and neither hydrocolloids type nor drying temperature had a significant effect on pH value of reconstituted doogh powder ($P > 0.05$). On the other hand, there was no significant difference between fresh doogh and reconstituted doogh powder, which showed that spray drying was not too severe to inactive the microorganisms. Sahan *et al.* (2008) revealed that acidity was independent of hydrocolloids for yogurt.

Serum Separation

Phase separation is considered as a hardship for fermented products preservation and is due to the casein protein's precipitation in isoelectric pH. Numerous researches have been investigating the effect of hydrocolloids as a usual additive to prevent serum separation (Foroughinia *et al.*, 2007; Tromp *et al.*, 2004). (Figure 2-d) shows that increasing drying temperature led to more serum separation ($P < 0.01$). Generally, the thermal process in milk and its derivatives, especially in the presence of lactic acid, leads to less solubility, which is attributed to the casein's instability and permanent denaturation resulting in more precipitation and serum separation. Tragacanth-treated doogh had considerable effect on serum separation ($P < 0.01$).

It works as a potential hydrocolloid in order to stabilize solutions even in low concentrations of gum and pH of the solution. Tragacanth has two fractions including water-soluble (40–30% of GT) and water-insoluble (60–70% of GT). The soluble part makes electrostatic bonds between carboxyl groups in galactronic acid and caseins, then, peripheral branches related to the main branch organize layer around the casein particles and, consequently, prevent particle agglomeration and precipitation, while insoluble parts involve in increasing viscosity and trapping particles. Foroughinia *et al.* (2007) stated that doogh serum separation can be banned at $pH > 4.00$ by tragacanth, which is independent to pH (Azarikia and Abbasi, 2010; Foroughinia *et al.*, 2007). However, differences were not

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Table 4. Experimental and modeled values of doogh optimization using response surface methodology.

	Porosity (%)	pH	Lightness	Serum separation %	Hausner ratio (%)	Carr index	Solubility (%)	Density (g cm^{-3})	Moisture Content (%)
Experimental value	73.54	4.32	89.58	65	1.59	37	88	0.31	5
Modeled value	71.3	4.33	89.82	61.8	1.55	35.48	87.13	0.29	5.18
Percentage of deviation from experimental value	3.04	0.23	0.27	4.92	2.52	4.1	0.99	6.45	3.6

Table 5. Sensory evaluation of reconstituted doogh powder in comparison to commercial control sample.

Properties[a]	Control	Reconstituted doogh
Color [ns]	6.07 ± 0.96	5.34 ± 1.05
Aroma [ns]	6.00 ± 1.00	5.20 ±1.47
Taste [ns]	5.67 ± 1.05	4.87 ± 1.30
Consistency [ns]	6.13 ± 0.83	5.67 ± 1.18
Overall acceptability [ns]	5.73 ±0.70	5.00 ± 1.06

[a] ns: Not significant.

significant between pectin containing sample and the control, due to the effect of low pH of doogh on pectin (P> 0.05). Azarikia and Abbasi (2010) revealed that this gum was not able to affect solutions at pH 4.

High temperature caused an increase of serum separation in the samples containing pectin and the control. However, tragacanth-treated doogh was not affected by the high temperature, due to its soluble part.

Model Assessment

The present study was undertaken to optimize quality factors such as water content, serum separation, pH, cohesion, porosity, and highest density, solubility, flowability, and brightness using response surface methodology. The results showed that the tragacanth treated sample dried at 122°C was the optimized conditions. Table 4 compares the experimental and predicted values by the model. The percentage of deviations of modeled data from experimental values indicated the suitability of the model for optimization.

Sensory Evaluation

Fresh doogh as the control and the reconstituted optimized doogh were assessed by 15 panelists for taste, color, consistency, aroma, and overall acceptability. As shown in Table 5, there were no significant differences between sensory attributes of samples (P> 0.05), which indicated that optimized reconstituted treatment had the least difference with the control and approved the proper conditions of spray drying based on sensory point of view.

CONCLUSIONS

Spray drying of doogh leads to many advantages for storage and transportation, therefore, selection of suitable stabilizer for spray drying is critical. In this study, optimization of the temperature of spray drier and concentration and type of hydrocolloids were performed. Based on the physicochemical analysis, the best powder was obtained at 122°C using tragacanth.

[DOR: 20.1001.1.16807073.2021.23.5.2.3]

Higher inlet air temperature caused lower lightness and higher serum separation of doogh. The bulk density values of powders were in the range of 0.23-0.36 g cm^{-3}, which were classified as low-density powders. All the doogh powders produced by spray drying with different carriers had solubility in the range of 78.3-90.4%, high porosity (63.3-75.8%), poor flowability (29-40%) and high cohesiveness (Hausner ratio of 1.41-1.61), with pH value in the range of 4.3 to 4.38. Based on the obtained results, dried doogh can be produced in a large scale due to better physical and chemical stability.

REFERENCES

1. Atomizer, A. S. N. 1978. Analytical Methods for Dry Milk Products. In: "*Method A11b*". Copenhagen, Denmark: A/S Niro Atomizer.
2. Azarikia, F. and Abbasi, S. 2010. On the Stabilization Mechanism of Doogh (Iranian yoghurt drink) by Gum Tragacanth. *Food Hydrocoll.*, **24**: 358-363.
3. Banavara, D. S., Anupama, D. and Rankin, S. A. 2003. Studies on Physicochemical and Functional Properties of Commercial Sweet Whey Powders. *J. Dairy Sci.,* **86(12):** 3866-3875.
4. Choi, H. S. and Kosikowski, F. V. 1985. Sweetened Plain and Flavored Carbonated Yogurt Beverages. *J. Dairy Sci.,* **68(3)**: 613-619.
5. Davoodi, H., Esmaeili, S. and Mortazavian, A. M. 2013. Effects of Milk and Milk Products Consumption on Cancer: A Review. Compr. Rev. *Food Sci. Food Saf.*, **12(3):** 249-264.
6. De Marchi, M., Penasa, M., Zidi, A. and Manuelian, C. L. 2018. Invited Review: Use of Infrared Technologies for the Assessment of Dairy Products: Applications and Perspectives. *J. Dairy Sci*., **101:** 10589-10604.
7. Eastman, J. E. and Moore, C. O. 1984. *U.S. Patent No. 4,465,702*. Washington, DC: U.S. Patent and Trademark Office.
8. Eastman, M. U. H., Hshib, S. A. and Ibrahim, U. K. 1984. Effect of Inlet Temperature on Pineapple Powder and Banana Milk Powder. *Procedia - Soc. Behav. Sci.,* **195**: 2829-2838.
9. Erbay, Z., Koca, N., Kaymak-Ertekin, F. and Ucuncu, M. 2015. Optimization of Spray Drying Process in Cheese Powder Production. *Food Bioprod. Process.,* **93:** 156-165.
10. Fazaeli, M., Emam-Djomeh, Z., Kalbasi Ashtari, A. and Omid, M. 2012. Effect of Spray Drying Conditions and Feed Composition on the Physical Properties of Black Mulberry Juice Powder. *Food Bioprod. Process.,* **90(4):** 667-675.
11. Foroughinia, S., Abbasi, S. and Hamidi Esfahani, Z. 2007. Effect of Individual and Combined Addition of Salep, Tragacanth and Guar Gums on the Stabilization of Iranian Doogh *J. Nut. Sci. Food. Tech.*,**2**:15-25.
12. Ganesan, V., Rosentrater, K. A. and Muthukumarappan, K. 2008. Flowability and Handling Characteristics of Bulk Solids and Powders: A Review with Implications for DDGS. *Biosys. Eng.,* **101(4):** 425-435.
13. Goula, A. M. and Adamopoulos, K. G. 2010. A New Technique for Spray Drying Orange Juice Concentrate. *Innov. Food Sci. Emerg. Technol.,* **11(2):** 342-351.
14. Jay, J. M. 1995. Fermentation and Fermented Dairy Products. In: "*Modern Food Microbiology"*, (Ed.): Jay, J. M. Springer US, Boston, MA, PP. 131-148.
15. Jinapong, N., Suphantharika, M. and Jamnong, P. 2008. Production of Instant Soymilk Powders by Ultrafiltration, Spray Drying and Fluidized Bed Agglomeration. *J. Food Eng.* **84(2):** 194-205.
16. Joudaki, H., Mousavi, M., Safari, M., Razavi, S. H., Emam-Djomeh, Z. and Gharibzahedi, S. M. 2013a. A Practical Optimization on Salt/High-Methoxyl Pectin Interaction to Design a Stable Formulation for Doogh. *Carbohydr. Polym.,* **97(2):** 376-383.
17. Joudaki, H., Mousavi, M., Safari, M., Razavi, S. H., Emam-Djomeh, Z. and Gharibzahedi, S. M. 2013b. Scrutinizing the

Different Pectin Types on Stability of an Iranian Traditional Drink "Doogh". *Int. J. Biol. Macromol.,* **60:** 375-382.
18. Karimifard, S. and Alavi Moghaddam, M. R. 2018. Application of Response Surface Methodology in Physicochemical Removal of Dyes from Wastewater: A Critical Review. *Sci. Total Environ.,* **640-641:** 772-797.
19. Kiani, H., Mousavi, M., Razavi, H. and Morris, E. 2010. Effect of Gellan, Alone and in Combination with High-Methoxy Pectin, on the Structure and Stability of Doogh, a Yogurt-Based Iranian Drink. *Food.Hydrocoll.,**24**:744-754.*
20. Koc, B., Sakin-Yilmazer, M., Kaymak-Ertekin, F. and Balkir, P. 2014. Physical Properties of Yoghurt Powder Produced by Spray Drying. *J. Food Sci. Technol.,* **51(7):** 1377-1383.
21. Koc, B., Yilmazer, M. S., Balkır, P. and Ertekin, F. K. 2010. Spray Drying of Yogurt: Optimization of Process Conditions for Improving Viability and Other Quality Attributes. *Dry. Technol.* **28(4):** 495-507.
22. Koç, B., Yilmazer, M. S., Balkır, P. and Ertekin, F. K. 2010. Moisture Sorption Isotherms and Storage Stability of Spray-Dried Yogurt Powder. *Dry. Technol.,* **28(6):** 816-822.
23. Mena-Sanchez, G., Babio, N., Martinez-Gonzalez, M. A., Corella, D., Schroder, H., Vioque, J., Romaguera, D., Martinez, J. A., Lopez-Miranda, J., Estruch, R., Warnberg, J., Bueno-Cavanillas, A., Serra-Majem, L., Tur, J. A., Aros, F., Tinahones, F. J., Sanchez, V. M., Lapetra, J., Pinto, X., Vidal, J., Vazquez, C., Ordovas, J. M., Delgado-Rodriguez, M., Matia-Martin, P., Basora, J., Buil-Cosiales, P., Fernandez-Carrion, R., Fito, M. and Salas-Salvado, J. 2018. Fermented Dairy Products, Diet Quality, and Cardio-Metabolic Profile of a Mediterranean Cohort at High Cardiovascular Risk. *Nutr. Metab. Cardiovasc. Dis.,* **28(10):** 1002-1011.
24. Patel, R., Patel, M. and Suthar, A. 2009. Spray Drying Technology: An Overview. *Indian J. Sci. Technol.,* **2(10):** 44-47.
25. Reale, A., Di Renzo, T., Preziuso, M., Panfili, G., Cipriano, L. and Messia, M. C. 2019. Stabilization of Sourdough Starter by Spray Drying Technique: New Breadmaking Perspective. *LWT,* **99:** 468-475.
26. Rennie, P. R., Chen, X. D., Hargreaves, C. and Mackereth, A. R. 1999. A Study of the Cohesion of Dairy Powders. *J. Food Eng.,* **39(3):** 277-284.
27. Ruby Figueroa, R. A., Cassano, A. and Drioli, E. 2011. Ultrafiltration of Orange Press Liquor: Optimization for Permeate Flux and Fouling Index by Response Surface Methodology. *Sep. Purif. Technol.,* **80(1):** 1-10.
28. Sahan, N., Yasar, K. and Hayaloglu, A. A. 2008. Physical, Chemical and Flavour Quality of Non-Fat Yogurt as Affected by a β-Glucan Hydrocolloidal Composite during Storage. *Food Hydrocoll.,* **22(7):** 1291-1297.
29. Sahin, S. and Sumnu, S. G. 2007. *Physical Properties of Foods*. Springer, New York.
30. Saw, H. Y., Davies, C. E., Paterson, A. H. J. and Jones, J. R. 2015. Correlation between Powder Flow Properties Measured by Shear Testing and Hausner Ratio. *Procedia Eng.* **102:** 218-225.
31. Straatsma, J., Van Houwelingen, G., Steenbergen, A. E. and De Jong, P. 1999. Spray Drying of Food Products: 2. Prediction of Insolubility Index. *J. Food Eng.,* **42(2)**: 73-77.
32. Teijeiro, M., Pérez, P. F., De Antoni, G. L. and Golowczyc, M. A. 2018. Suitability of Kefir Powder Production Using Spray Drying. *Food Res. Int.* **112**: 169-174.
33. Teimouri, S., Abbasi, S. and Scanlon, M. G. 2018. Stabilisation Mechanism of Various Inulins and Hydrocolloids: Milk–Sour Cherry Juice Mixture. *Int. J. Dairy Technol.,* **71(1):** 208-215.
34. Telfser, A. and Gómez Galindo, F. 2019. Effect of Reversible Permeabilization in Combination with Different Drying Methods on the Structure and Sensorial Quality of Dried Basil (*Ocimum basilicum* L.) Leaves. *LWT,* **99:** 148-155.
35. Tromp, R., De Kruif, C. G., van Eijk, M. and Rolin, C. 2004. On the Mechanism of

Stabilisation of Acidified Milk Drinks by Pectin. *Food. Hydrocoll.*,**18**:565-572

36. Walton, D. E. 2000. The Morphology of Spray-Dried Particles a Qualitative View. *Dry. Technol.,* **18(9):** 1943-1986.

پایدارسازی و بهینه‌سازی پودر دوغ با استفاده از هیدروکلوئیدها: تولید و بررسی ویژگی‌ها

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چکیده

دوغ یکی نوشیدنی لبنی اسیدی مطبوع است که واسطه رشد میکروبی و به هم چسبیدن پروتئین ها در نتیجه جداشدن فازها به دلیل pH پایین دارای پایداری پایین بوده و همچنین موجب بادکردگی در بسته می شود. در این پژوهش بهینه‌سازی تولید پودر دوغ پایدار شده با پکتین و کتیرا با استفاده از روش رویه پاسخ برای یافتن هیدروکلوئید و شرایط فرآوری مناسب انجام شد. نتایج نشان داد ویژگی‌های پودر دوغ خشک بشدت ($p< ۰/۰۵$) وابسته به دمای خشک‌کن پاششی و نوع هیدروکلوئید است. شرایط بهینه تولید در دمای ورودی خشک‌کن پاششی برابر ۱۲۲ ^{o}C و با استفاده از کتیرا بود. تحت این شرایط پودر دوغ دارای محتوای رطوبت، دانسیته توده، انحلال، اندیس Carr، درصد جداسازی سرم، رنگ (روشنایی)، pH، نسبت هاسنر و تخلخل بترتیب برابر ۵٪، ٪ ۰/۳۱، ٪ ۰/۸۸، ۳۷، ٪ ۶۵، ۸۹، ۴/۳۳، % ۱/۵۹ و ٪ ۷۳/۵ بود. نتایج داده‌های ارزیابی حسی (رنگ، بو، طعم، قوام و پذیرش کلی) مبین این بود که تفاوت معنی‌داری بین دوغ حاصل از پودر تولید شده در شرایط بهینه بازسازی شده با نمونه تازه وجود ندارد.

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