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Research note

Analysis of the Effective Parameters on Potato Powder Quality Produced by a Spray Dryer

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Abstract

Spray dryer was used to produce potato powder from potato juice. Turning potatoes into powder will increase its substance durability, ease of transportation and the storage. The important factors affecting the powder produced by spray dryer include inlet air temperature, volumetric flow rates of feed and air. Experiments were conducted according to Taguchi's method by considering 3 levels for each one of the mentioned parameters and 2 levels for atomizer's nozzle diameter. The objective was to obtain the optimized process conditions for producing potato powder with desirable color. By analyzing the experimental results, the optimized conditions for producing potato powder by spray dryer were determined. It was also revealed that by adding 1 percent maltodextrin (dry mass basis) to the feed, the product's adhesion will decrease significantly and the amount of product will be increased.

Keywords: *Potato Powder, Spray Dryer, Color*

1. Introduction

Potatoes are highly nutritious vegetables. About 20 to 30 percent of potato is dry matter with a high percentage of starch. Other considerable portions of dry matter consist of sugar and dietary fiber. Proteins and lipids are present in a lesser quantity. Orange fleshed potatoes are often recognized as containing a significant amount of beta-carotene, a pre-cursor to vitamin A. Potatoes are a substantial source of vitamin C and several other minerals [17]. This vegetable is a multi-purpose nutrient in the food industry. Production of many kinds of chips, fast foods, sandwiches, etc. has made this nutritious matter very popular but preservation, transport and storage of fresh potato has always been of major concern in the food industry. There has been a decrease in potato consumption in the past several decades due to difficulties in storage, availability, handling and the limited product choices for consumers [7].

One easy way for preservation, transportation and consumption of potato is to turn the potato juice into a dried powder. This approach is attractive to both producers and consumers. Fruit and vegetable powders

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can be used as food supplement and useful for human health. Many kinds of organic materials such as fruit juices, potato puree, tomato pulp and pineapples have been dried through spraying method [6,12,1,9,13,14].

Fruit and vegetable powders have been shown to have some desirable effects such as color, flavor, water binding and additional nutrients [8]. Potato flour can be used as a thickener in foods such as soup, gravy, fabricated snacks and bakery products [15]. Operational conditions, type and amount of additives are very effective on final product characteristics. To improve the performance of the spray dryer for potato powder production, some methods have been suggested such as reduction of feed viscosity and product stickiness [11]. Stickiness, hygroscopicity and solubility are some property problems of fruit powders due to the presence of low molecular weight sugars and acids which have low glass transition temperature [4]. In the majority of previous works, drying additives or carriers have been utilized to reduce the stickiness of sugar-rich foods and reduce wall deposition problems. Many of these drying aids such as starches, maltodextrins, corn syrups and gum Arabic have high molecular weights and high glass transition temperatures [13]. Maltodextrin as a drying additive increases the glass transition temperature of the product [5,10]; it also has a bland flavor, good solubility and is often used as a bulking agent [3].

Grabowski et al. [11] determined the effects of viscosity reduction of potato puree with alpha-amylase, maltodextrin addition and inlet air temperature on the physicochemical characteristics of spray dried potato powder. In 2008 Grabowski et al. examined nutrient composition and rheological properties of the hydrated spray dried potato powders produced with various levels of amylase and maltodetrin and compared them with the potato puree [12]. Ahmed et al. [2] investigated the production of encapsulated flours from purple-fleshed sweet potato by spray drying with combinations of various levels of ascorbic acid, maltodextrin and also physicochemical and morphological properties.

The objective of this study was to investigate the feed and inlet air flow rates, inlet air temperature and the maltodextrin addition as an additive on quality of potato powder produced by a spray dryer.

2. Material and methods

The potato used for the experiments was purchased from the vicinity of Isfahan province, in the center of Iran. As mentioned earlier, about 70 to 80 percent of the potato is water and the rest is dry matter. Maltodextrin with a DE[1] of about 16.5 to 19.5 was purchased from the Merck agent in Iran. The potato was skinned and the juice was extracted and filtered. The juice was constantly stirred to remain homogeneous and not allow the solid particles to settle.

Spray drying experimental tests were conducted by a lab scale dryer (Labplant SD – 05, Armfield, England). The device had a two-fluid nozzle for atomizing the feed. Feed and air flow was co-current. The air was heated by an electrical heating element. The heater power was 0.5 to 3 kW and was equipped with a fan for air supply. The heater was capable of increasing the air temperature up to 400°C. A peristaltic pump

1. Dextrose Equivalent

was used to pump the feed into the dryer. The feed entered the drying chamber concurrently with air. The produced powder was separated from air by a cyclone. The tests were carried out three times for each group of samples, only mean values are reported.

3. Experimental design

Four independent variables including inlet drying air temperature, feed flow rate, air flow rate and nozzle diameter were used in designing the experiments. Three temperature levels (185, 195 and 205 °C) were considered for inlet drying air, along with three flow rate levels (5.5, 9 and 12.5 mL/min) for feed, three flow rate levels (1.225×10^{-3}, 1.715×10^{-3} and $2.205\times10^{-3} m^3/s$) for air and two levels (0.5 and 0.7 mm) for atomizer nozzle diameter. The Taguchi method using Minitab software was applied for designing the experiments. According to this method 18 experiments were conducted; the desired responses were the color and moisture content of the product.

4. Powder analysis

The product color was measured using Textflash colorimeter (Datacolor, Swiss). Product color measurements were carried out directly on the sample surface by reflection and were expressed as L^*(lightness), a^* (redness) and b^* (yellowness) parameters. L^* value range from black (-) to white (+),a^* values range from green (-) to red (+) and b^* values range from blue (-) to yellow (+). Hue angle (H^*) and color change (ΔE) (color change compared to the standard sample) was obtained through the following equations (Hutchings, 1994):

$$H^* = \arctan(\frac{b^*}{a^*}) \tag{1}$$

$$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2} \tag{2}$$

Final moisture content of each product was determined by an electrical oven (Behdad-50, Iran). By putting the product into the oven and heating it at 120 ^{o}C for at least 48 h until no further weight change was observed and then calculating the difference between initial and final weights, the moisture content was obtained.

5. Results and discussion

5-1. Moisture content of product

The results of moisture content, stickiness and efficiency of products (the amount of product obtained from a specific amount of feed) are presented in Table 1.

In Table 1, four samples are specified as desired. Since the final objective was to determine the optimum operation conditions, the following points should be mentioned:

1- To save energy, it is better to minimize the inlet air temperature. On the other hand, the air temperature should be high enough to reach the allowed moisture content for product. At high levels of feed flow rate, the inlet air temperature should be high and for low temperatures, air flow rate should be increased. The moisture contents of the product were acceptable at air temperatures 195 and 205°C; therefore, 195°C was chosen as the optimum air temperature.

2- Air is an abundant and readily available resource, so the air flow rate can be set at the highest levels. Increasing the air flow rate would increase the outlet air temperature and this in turn would increase the thermal driving force and mass transfer coefficient and reduce the final moisture content.

The elevated air flow rate would improve the performance of separating the product from air in the cyclone but it should be noted that at high air temperatures, the elevated air flow rate would lead to the opaqueness of the product. Likewise, the elevated air flow rate would reduce the residence time of droplets of potato juice in the drier and increase the moisture in the final product.

Table 1. The process conditions for drying the potato juice in spray dryer

Run	T_{air} (°C)	Feed Flow (mL/min)	Air Flow (m^3)×1000	D_{nozzie} (mm)	Moisture content (%) (wet basis)	Condition
1	185	5.5	1.225	0.5	3.902	Desired
2	195	9	1.225	0.5	5.928	A little sticky, desired moisture, relatively good efficiency
3	205	12.5	1.225	0.5	394.7	Sticky, high moisture, low efficiency
4	185	5.5	1.715	0.5	569.6	A little sticky, high moisture, relatively good efficiency
5	195	9	1.715	0.5	668.4	Desired
6	205	12.5	1.715	0.5	849.6	A little sticky, high moisture, low efficiency
7	195	5.5	2.205	0.5	895.5	Desired stickiness, low moisture, desired efficiency
8	205	9	2.205	0.5	307.6	Desired stickiness, low moisture, good efficiency
9	185	12.5	2.205	0.5	573.5	Sticky, relatively high moisture, relatively good efficiency
10	205	5.5	1.225	0.7	399.5	A little sticky, a little opaque and burned, relatively good efficiency
11	185	9	1.225	0.7	975.8	Sticky, wet, low efficiency
12	195	12.5	1.225	0.7	88.5	A little sticky, wet, poor efficiency
13	195	5.5	1.715	0.7	824.4	Desired
14	205	9	1.715	0.7	643.4	Desired
15	185	12.5	1.715	0.7	333.5	A little sticky, wet, relatively good efficiency
16	205	5.5	2.205	0.7	113.6	A little sticky, wet, good efficiency
17	185	9	2.205	0.7	13.6	A little sticky, wet, good efficiency
18	195	12.5	2.205	0.7	294.6	Sticky, wet, relatively good efficiency

Air flow rate should be chosen in a manner that it would reach an optimized condition. In the conducted experiments, the air flow rate of 0.002205 $\frac{m^3}{s}$ was better for separation; but due to low residence time of juice, it increased the moisture content of product; therefore, the flow rate of 0.001715 $\frac{m^3}{s}$ was chosen as the optimized condition.

3- Maximum production capacity is desired in food processing industry; therefore, the feed flow rate should be set at its highest possible level. It should be noticed that an excess increase in feed flow rate would increase the feed droplets size and reduce the residence time of the feed in the drying chamber, and the product moisture content would increase.

On the other hand, increasing the mass transfer coefficient will slightly neutralize the above-mentioned effects. The product characterization at feed flow rates of 5.5 and 9 mL/min were acceptable. By considering the above characteristics, 9 mL/min was chosen as optimized feed flow rate.

5-2. Color analysis results

The results of color analysis are presented in Table 2. D65 corresponds to the day light, A corresponds to the tungsten lamp light and TL84 corresponds to the fluorescent lamp light. L^*, a^* and b^* ranged from -100 to 100. High values of L^* signify whiter product, which is desired. High values of a^* signify more red product which is not desired and high values of b^* signify more yellow product which is desired, provided that the product color is similar to the initial color of the potato. The data for the color analysis of the standard sample (available in market, Peris Co., Iran) is presented in Table 3.

Table 2. Color analysis of potato powder samples

	D65					A					TL84				
No.	**L***	**a***	**b***	**H***	**ΔE**	**L***	**a***	**b***	**H***	**ΔE**	**L***	**a***	**b***	**H***	**ΔE**
1	54.84	7.27	16.21	1.15	27.5	56.73	9.99	18.42	1.07	26.5	55.92	7.21	18.24	1.19	26.9
2	49.53	3.76	10.92	1.24	32.7	50.70	5.92	12.13	1.12	32.4	50.22	3.91	12.23	1.26	32.8
3	44.07	6.59	14.27	1.14	38.0	45.75	8.84	16.41	1.08	37.2	45.05	6.50	16.03	1.19	37.6
4	53.34	3.76	10.59	1.23	29.1	54.50	5.85	11.81	1.11	28.7	54.03	3.91	11.89	1.25	29.1
5	54.79	5.45	12.82	1.17	27.7	56.27	7.50	14.73	1.10	26.7	55.71	5.26	14.44	1.22	27.1
6	54.46	8.34	14.54	1.05	28.3	56.39	10.68	17.02	1.01	27.0	55.55	8.14	16.47	1.11	27.6
7	51.64	5.46	13.03	1.17	30.5	53.13	7.55	14.92	1.10	29.8	52.56	5.30	14.56	1.22	30.2
8	50.86	4.88	12.36	1.20	31.3	52.25	6.81	14.16	1.12	30.6	51.74	4.77	13.89	1.24	31.1
9	54.76	8.14	14.36	1.05	28.0	56.65	10.20	16.98	1.03	26.7	55.86	7.81	16.2	1.12	27.3
10	49.94	5.37	12.8	1.17	32.2	51.41	7.49	14.63	1.10	31.5	50.83	5.29	14.38	1.21	31.9
11	49.64	6.39	14.47	1.16	32.5	51.32	8.66	16.59	1.09	31.6	50.65	6.26	16.28	1.20	32.0
12	54.72	5.82	16.79	1.24	27.3	56.47	8.65	18.77	1.14	26.5	55.78	5.86	18.82	1.27	26.8
13	51.63	6.14	18.17	1.25	30.4	53.48	8.98	20.35	1.16	29.7	52.78	6.05	20.34	1.28	29.8
14	55.74	5.78	13.75	1.17	26.5	57.32	7.83	15.86	1.11	25.6	56.76	5.51	15.50	1.23	26.0
15	53.88	3.75	14.58	1.32	27.9	55.26	5.99	16.27	1.52	27.4	54.85	3.53	16.33	1.36	27.6
16	52.62	6.04	13.43	1.15	29.6	54.21	8.16	15.52	1.09	28.7	53.58	5.89	15.16	1.20	29.2
17	53.41	3.79	10.91	1.24	28.9	54.58	5.83	12.23	1.13	28.5	54.12	3.90	12.24	1.26	29.0
18	49.88	5.63	12.83	1.16	32.3	51.38	7.63	14.78	1.09	31.5	50.80	5.40	14.42	1.21	32.0

Table 3. Color analysis of standard potato powder samples

D65				A				TL84			
L*	**a***	**b***	**ΔE**	**L***	**a***	**b***	**ΔE**	**L***	**a***	**b***	**ΔE**
81.426	0.205	17.112	1.559	82.576	4.037	17.448	1.339	82.192	1.297	18.881	1.502

The color of the product depends on inlet air temperature, air flow rate and feed flow rate and it is not possible to examine the effect of these parameters separately. Based on the color analysis of Tables 1 and 2, the following results could be obtained:

1- At low feed flow rates, hot air causes the product to become opaque.
2- Redness of the product strongly depends on the feed flow rate. If the feed flow rate is high, then the product will be wet and red in color. Moreover, the flow rate and air temperature have a small effect on product redness.
3- Yellowness of the product strongly depends on inlet air temperature. If the air temperature is high then the yellowness will be higher. High hot air flow rate would make the product more yellow and opaque. Also, two other parameters are effective.
4- In the optimized conditions any given rise in air temperature would make the product more red, yellow and opaque.
5- In the optimized conditions any given rise in air flow rate would make the product more red and yellow.
6- In the optimized conditions any given rise in feed flow rate would make the product more red and wet.

5-3. Effect of maltodextrin addition

As mentioned earlier, adding maltodextrin to the potato juice would reduce the glass transition temperature; hence, a reduction in product adhesion and an increase in dryer efficiency. The amount of the product increased 2.5 times when one percent maltodextrin was added to the juice (see experiment 19).

The other effect of maltodextrin was on color of the product. The 19th and 20th experiments were conducted in optimized conditions (like the 5th experiment) with the exception that 1 and 0.75 percent maltodextrin were added to the feed respectively; the results are shown in Table 4. Here, it can be seen that L^* has been increased and the product is whiter relative to the similar feed without maltodextrin. Grabowski et al. [11] reached the same conclusion indicating that by an increase in maltodextrin level the product will be whiter and less orange colored.

6. Conclusion

The moisture content is a very important factor in determining the quality of the product. Allowable product moisture content ranges from 3 to 5 percent. By optimizing the inlet air temperature, feed flow rate, air flow rate and other parameters, the allowable product moisture can be achieved.

The other important parameter in determining the quality is the product color. Potato powder should not be opaque. High inlet air temperature causes the product to become opaque.

Table 4. Color analysis of potato powders with maltodextrin

	D65					A					TL84				
No.	**L***	**a***	**b***	**H***	**ΔE**	**L***	**a***	**b***	**H***	**ΔE**	**L***	**a***	**b***	**H***	**ΔE**
19	55.81	4.39	16.85	1.32	25.9	57.13	6.52	19.02	1.24	25.6	56.73	3.65	19.01	1.38	25.6
20	54.94	6.36	16.12	1.19	27.2	56.66	8.67	18.46	1.13	26.3	55.9	6.04	18.10	1.25	26.7

Another important fact is that the potato powder should not be sticky. By using additives like maltodextrin, the adhesion will be reduced and the powder will be whiter.

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