Study on Fluidity and Floodability Of Different Potato Powders

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Abstract. The parameters of particle image, particle size, length-diameter ratio, circularity, angle of repose, angle of collapse, angle of difference, plate angle, apparent density, dispersity, tap density, degree of compression, porosity, uniformity, etc. of different powders were tested in order to study the fluidity and floodability of four different potato powders, respectively potato flakes, homemade potato starch, potato starch and grain potato powder. Carr point-weighted method was adopted for evaluating fluidity and floodability of different potato powders. The results show that fluidity: potato flakes> grain potato powder > homemade potato starch> potato starch, floodability: homemade potato starch> potato starch > grain potato powder >potato flakes.

1. Materials and methods

1.1. Materials and reagent
Potato flakes, potato starch, homemade potato starch, grain potato powder and isobutanol were applied; wherein homemade potato starch belongs to potato starch which is prepared manually. The remaining products and reagents are sold in the market.

1.2. Test instrument and equipment
Bt-1001 powder comprehensive characteristic tester which is produced by Dandong Baxter Instrument Co., Ltd.; BT-1600 Baxter image particle analyzer which is produced by Dandong Baxter Instrument Co. Ltd.

1.3. Test method

1.3.1. Test of particle image, particle size, length-diameter ratio and circularity of different potato powders. Samples were obtained from four points of tested samples, which were divided to obtain the required content for final test. The samples were added into isobutanol liquid and configured to 0.30% solution. The suspension liquid is fully mixed with a mixer for 60 seconds, and then sampling instruments were used for sampling several milliliters from the liquid. The sampling instruments were inserted into the liquid. Many points were selected, and the liquid was sampled at different depths of the same point, which was dripped to the slide. It was covered with glass. The slide was placed on the cargo platform. The microscope image was observed. After the computer was connected, the particle
image was observed on the computer, and then particle size, length-diameter ratio and circularity were tested.

1.3.2. Test of fluidity and floodability of different potato powders. BT-1001 powder comprehensive characteristic tester was utilized for sampling different samples according to related requirements. Angle of repose, angle of collapse, angle of difference, plate angle, apparent density, dispersity, tap density, degree of compression, porosity and uniformity were tested aiming at different samples. Each test was repeated for three times. Meanwhile value was obtained for obtaining final data. The fluidity index and floodability index were calculated for the result data by Carr point-weighted method (attached table 1 and attached table 2).

2. Results and analysis

2.1. Analysis on particle image of different potato powders

![Figure 1. potato flakes (4×)](image1)
![Figure 2. potato flakes (10×)](image2)
![Figure 3. potato flakes (40×)](image3)

![Figure 4. potato starch (4×)](image4)
![Figure 5. potato starch (10×)](image5)
![Figure 6. potato starch (40×)](image6)

![Figure 7. homemade potato starch (4×)](image7)
![Figure 8. homemade potato starch (10×)](image8)
![Figure 9. homemade potato starch (40×)](image9)
Figure 10. grain potato powder (4×) Figure 11. grain potato powder (10×) Figure 12. grain potato powder (40×)

Figure 1 to Figure 12 are the photos of four different potato powders under 4×, 10×, 40× microscopes respectively. The figure shows that potato flakes show irregular polygon shapes, and the particles are the greatest as a whole. The properties of grain potato powder are similar to the potato flakes, the fluidity is good, and floodability is strong. The density requirements on packaging materials are lower than that on the potato starch during packaging. The potato flakes are not easy to accumulate in the process of processing and transmission, and the required conveying pressure is lower. The difference among potato starch particles is smaller than that of homemade potato starch particles. The polymerization of potato starch granules is larger, the fluidity is poor, the floodability is good, tighter materials are required in the process of packaging. The potato starch is easy to accumulate during processing and conveying. The required conveying pressure is relatively low.

2.2. Analysis on particle size of different potato powders

Figure 13. potato flakes Figure 14. homemade potato starch

Figure 15. potato starch Figure 16. grain potato powder

The above table shows that 80.32% potato flake particle distribution is within the interval of 24.74 to 35.33um, particle proportions of homemade potato starch particle and grain potato powder distribution within 2.91 to 4.16um interval are 33.79% and 34.03%. particle distribution of 60.93% potato starch is within the interval of 1.00 to 1.43um interval, potato flakes have the largest particle size generally, which is followed by grain potato powder, potato starch has the smallest particle size generally.
Table 1. Particle size distribution of different potato powders.

| Particle size interval (um) | Potato flakes | Homemade potato starch | Potato starch | Grain potato powder |
|-----------------------------|---------------|------------------------|---------------|---------------------|
| Interval distribution (%)   | Interval distribution (%) | Interval distribution (%) | Interval distribution (%) | Interval distribution (%) |
| 1.00 to 1.43                | 0.01          | 16.26                  | 60.93         | 0.45                |
| 1.43 to 2.04                | 0.03          | 20.76                  | 32.19         | 3.72                |
| 2.04 to 2.91                | 0.08          | 28.38                  | 6.20          | 16.16               |
| 2.91 to 4.16                | 0.06          | 33.79                  | 0.52          | 34.03               |
| 4.16 to 5.94                | 0.17          | 0.81                   | 0             | 26.28               |
| 5.94 to 8.49                | 1.93          | 0                      | 0             | 19.36               |
| 8.49 to 12.13               | 3.40          | 0                      | 0             | 0                   |
| 12.13 to 17.32              | 0.90          | 0                      | 0             | 0                   |
| 17.32 to 24.74              | 13.10         | 0                      | 0.17          | 0                   |
| 24.74 to 35.33              | 80.32         | 0                      | 0             | 0                   |
| 35.33 to 50.47              | 0             | 0                      | 0             | 0                   |

2.3. Analysis on length-diameter ratio of different potato powders

Table 2. Length-diameter ratio distribution of different potato powders

| Length-diameter ratio interval | Potato flakes | Homemade potato starch | Potato starch | Grain potato powder |
|-------------------------------|---------------|------------------------|---------------|---------------------|
| Interval distribution (%)     | Interval distribution (%) | Interval distribution (%) | Interval distribution (%) | Interval distribution (%) |
| 1.00 to 2.00                  | 56.19         | 89.34                  | 77.27         | 76.56               |
| 2.00 to 4.00                  | 36.71         | 9.64                   | 22.22         | 21.56               |
| 4.00 to 6.00                  | 3.93          | 1.02                   | 0.51          | 1.88                |
| 6.00 to 8.00                  | 0.76          | 0                      | 0             | 0                   |
| 8.00 to 10.00                 | 1.66          | 0                      | 0             | 0                   |
| 10.00 to 12.00                | 0.60          | 0                      | 0             | 0                   |
| 12.00 to 14.00                | 0             | 0                      | 0             | 0                   |
| 14.00 to 16.00                | 0             | 0                      | 0             | 0                   |
| 16.00 to 18.00                | 0             | 0                      | 0             | 0                   |
| 18.00 to 20.00                | 0             | 0                      | 0             | 0                   |
| 20.00 to 22.00                | 0             | 0                      | 0             | 0                   |
| 22.00 to 24.00                | 0.15          | 0                      | 0             | 0                   |
| 24.00 to 26.00                | 0             | 0                      | 0             | 0                   |

The above table shows that the interval proportion of potato flakes, homemade potato starch, potato starch and grain potato powder from 1.00 to 2.00 is respectively 56.19%, 89.34%, 77.27% and 76.56%. Homemade potato starch particle is the closest to conformity in general, which is followed by potato starch and grain potato powder. Potato flake particle is the least similar to conformity.
2.4. Analysis on length-diameter ratio of different potato powders

Table 3. Circularity distribution of different potato powders

| Circularity interval | Potato flakes | Homemade potato starch | Potato starch | Grain potato powder |
|----------------------|---------------|-----------------------|--------------|--------------------|
|                      | Interval distribution (%) | Interval distribution (%) | Interval distribution (%) | Interval distribution (%) |
| 0.100 to 0.120       | 0             | 0                     | 0            | 0                  |
| 0.120 to 0.130       | 0             | 0                     | 0            | 0                  |
| 0.130 to 0.150       | 0             | 0                     | 0            | 0                  |
| 0.150 to 0.180       | 0             | 0                     | 0            | 0                  |
| 0.180 to 0.210       | 0             | 0                     | 0            | 0                  |
| 0.210 to 0.240       | 0             | 0                     | 0            | 0                  |
| 0.240 to 0.270       | 0.18          | 0.51                  | 0            | 0.31               |
| 0.270 to 0.320       | 0.37          | 0.51                  | 1.52         | 0.63               |
| 0.320 to 0.370       | 1.84          | 1.52                  | 2.02         | 1.56               |
| 0.370 to 0.420       | 1.10          | 3.55                  | 1.52         | 2.81               |
| 0.420 to 0.490       | 5.89          | 4.06                  | 3.54         | 6.25               |
| 0.490 to 0.560       | 8.66          | 3.55                  | 6.06         | 8.13               |
| 0.560 to 0.650       | 25.29         | 4.06                  | 7.07         | 14.38              |
| 0.650 to 0.750       | 17.13         | 8.12                  | 15.66        | 20.63              |
| 0.750 to 0.870       | 24.68         | 23.86                 | 27.78        | 24.06              |
| 0.870 to 1.000       | 14.86         | 50.25                 | 34.85        | 21.25              |

The above table shows that potato flakes, homemade potato starch, potato starch and grain potato powder circularity from 0.870 to 1.000 interval respectively account for 14.86%, 50.25%, 34.85% and 21.25%; potato flakes and grain potato powder have worse circularity, most particles have different shapes. Homemade potato starch has the best particle circularity. Powder particle circularity is better, powder polymerization is better, the porosity is worse, fluidity is worse, floodability is better, powder independence is weaker, and powder piling property is stronger, and the results have stronger practical and application significance in storage and piling.

2.5. Analysis on fluidity of different potato powders

Fluidity index is the weighted sum of angle of repose, degree of compression, plate angle, uniformity and other indexes. The fluidity is evaluated according to attached table 2.

Table 4. Parameter test results of different potato powders

| Group                        | Potato flakes | Homemade potato starch | Potato starch | Grain potato powder |
|------------------------------|---------------|-----------------------|--------------|--------------------|
| Angle of repose (°)          | 35.34         | 44.27                 | 46.60        | 35.48              |
| Plate angle (°)              | 37.87         | 69.06                 | 71.84        | 43.58              |
| Degree of compression (%)    | 7.14          | 23.91                 | 21.25        | 10.87              |
| Uniformity/ agglomeration degree | 2.24         | 2.15                  | 2.14         | 2.19               |
Table 5. Analysis results of Carr point-weighted method fluidity of different potato powders

| Fluidity                           | Potato flakes | Homemade potato starch | Potato starch | Grain potato powder |
|------------------------------------|---------------|------------------------|--------------|-------------------|
| Angle of repose (°)                | 20.0          | 16.0                   | 12.0         | 20.0              |
| Degree of compression (%)          | 23.0          | 16.0                   | 17.0         | 22.0              |
| Plate angle (°)                    | 20.0          | 12.0                   | 12.0         | 18.0              |
| Uniformity/ agglomeration degree   | 23.0          | 23.0                   | 23.0         | 23.0              |
| Fluidity index                     | 86.0          | 67.0                   | 64.0         | 83.0              |
| Fluidity evaluation                | Good          | General                | General      | Good              |
| Arch prevention measures           | None          | Critical point of arching | Critical point of arching | None |

The above table shows that: potato flakes fluidity is the best, potato starch fluidity is the worst; since the water content of the grain potato powder is better than that of potato flakes, the water content of potato starch is more than that of grain potato powder. The porosity among potato starch powder particles is relatively small, the friction among particles is larger, and the fluidity is relatively poor. Potato flakes are thin slices. The porosity of particles is higher than that of grain potato powder. The porosity is higher, and the particle is looser. Potato flakes and grain potato powder have good fluidity, and arch prevention measures are not required during pipeline transportation. Homemade potato starch and potato starch have general fluidity, the prevention measure refers to arching critical point. The piling property of potato starch is the best, which is followed by homemade potato starch and grain potato powder, and the potato flakes is the worst.

2.6. Analysis on floodability of different potato powders

Floodability index is the weighed sum of fluidity index, angle of collapse, angle of difference, dispersity and other indexes [20]. The floodability is evaluated according to attached table 3.

Table 6. Parameter test results of different potato powders

| Group            | Potato flakes | Homemade potato starch | Potato starch | Grain potato powder |
|------------------|---------------|------------------------|--------------|-------------------|
| Angle of difference (°) | 5.43          | 13.77                  | 9.41         | 6.12              |
| Angle of collapse (°)    | 29.91         | 30.5                   | 37.19        | 29.36             |
| Dispersity (%)        | 3.60          | 19.33                  | 20.70        | 0.82              |

The powder floodability is obtained by comparison in floodability index table: homemade potato starch is the best, which is followed by potato starch and grain potato powder, and potato flakes is the worst. Reasons are analyzed as follows: potato starch has smaller particle, which is easy to adhere together. Potato flakes and grain potato powder particle are independent relatively [24], therefore floodability is weaker compared with potato starch; wherein homemade potato starch, grain potato powder and potato starch have quite strong floodability, cross seal is required is production and packaging, the required conveying pressure is smaller during pipeline transportation. Potato flakes have flooding tendency, cross seal is required sometimes, and larger conveying pressure is required.
Table 7. Floodability analysis results of different potato powders by Carr point-weighted method

| Floodability       | Index                  | Potato flakes | Homemade potato starch | Potato starch | Grain potato powder |
|--------------------|------------------------|---------------|------------------------|--------------|--------------------|
| Angle of difference|                        | 3.0           | 14.5                   | 9.5          | 6.0                |
| Angle of collapse  |                        | 17.5          | 17.0                   | 16.0         | 18.0               |
| Dispersity         |                        | 3.0           | 14.5                   | 16.0         | 3.0                |
| Fluidity index     |                        | 25.0          | 25.0                   | 25.0         | 25.0               |
| Fluidity index     |                        | 48.5          | 71.0                   | 66.5         | 52.0               |
| Fluidity degree    | Tendentious            | Cross seal is required sometimes. | Cross seal is required. | Cross seal is required. | Cross seal is required sometimes. |

3. Conclusion

The following conclusions are made in the experiment by testing the fluidity and floodability of four different potato powders: potato flake particle irregularity is strong, the particle size is the largest, the overall shape of powder is greatly different from conformity, the circularity is the worst, the fluidity is good, and it has the flooding tendency. Potato starch particle has excellent regularity, the particle size is the minimum, and the conformity is better, the circularity is better, the fluidity is general, and the floodability is quite strong. Homemade potato starch has similar properties as potato starch. Grain potato powder particle has better regularity, the particle size is smaller than the potato flakes, the conformity is better, the circularity is better than potato flakes. The fluidity is good, which is a little worse than potato flakes, and it has flooding tendency, which is a bit stronger than potato flakes.

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