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Study on the Physical and Chemical Properties of Potato Powder

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In this paper, we pregelatinize different varieties of potato powder, study the effect of heating intensity on the physical and chemical properties of potato powder, and at the same time determine the granularity distribution, viscosity parameters and amylose content of different varieties of potato powder and analyze the content variation ranges and concentrated distributions of potato powder granules with different shapes. We conduct qualitative analysis on the gelatinization temperature and viscosity of different potato powder granules, amylose, amylopectin and enthalpy variation during heating to provide basis for the deployment of the potato staple food strategy.

1. Introduction

Potato, a perennial herb in the nightshade family, is the world's fourth largest food crop. Its tuber is edible, which contains 15% - 24% starch. According to relevant survey, potato powder accounts for about one-third of the total amount of plant starch on the market, constituting an important source of plant starch. Potato, as a kind of staple food, is mainly made into steamed buns, noodles and other flour products. What affects the quality of these products most is the physical and chemical properties of potato powder during production and processing. There are many ways to produce potato powder, resulting in structural differences among different varieties of starch and further affecting the application of different varieties of potato powder in the actual production process. Therefore, studying different physical and chemical properties of different varieties of potato powder is of great significance to the processing of potato powder products and the implementation of the potato staple food strategy (Li, 2012).

1.1 Materials and reagents

Potato flakes, potato granules, potato starch, milled potato powder; phosphomolybdic acid, α-amylase, amylase standard product and amylopectin standard product. The above materials are all commercially available.

1.2 Testing apparatuses and equipment

DK-98-I electric-heated thermostatic water bath, manufactured by Jiangsu Muce Company; laser particle analyzer, manufactured by Shanghai Yuanda Company; digital viscosimeter, manufactured by Shanghai Lunjie Company; differential scanning calorimeter, manufactured by Shanghai Lunjie Company; detection microscope YYC-800, manufactured by Shanghai Yiyuan Optical Instrument Co., Ltd.; TG16-WS centrifuge, manufactured by Zhangjiagang Light Equipment Factory; UV-2550 ultraviolet spectrophotometer, manufactured by Jiangnan Fengxi Company; thermometer; DHG thermostatic drier box, manufactured by Jiangsu Xinruo Co., Ltd.; water bath oscillator, manufactured by Shanghai Hetian Company.

1.3 Testing methods

(1) Determination of moisture content in different varieties of potato powder
The determination method for moisture content in potato powder adopts the method for determination of moisture content in starches provided in the national standard – the oven-drying method (Peng et al., 2007);
(2) Determination of particle size distribution in different varieties of potato powder

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We weigh 0.5g of potato powder processed respectively by different methods, place it in the dish in the laser particle analyzer, add distilled water with 10 times dosage, and open the software to determine the particle size.

(3) Determination of amylose and amylopectin content in different varieties of potato powder

Regarding the determination method for the amylose and amylopectin content in different varieties of potato powder, we refer to GB/T 15683-2008 *Rice-Determination of Amylose Content*, and we conduct colorimetric analysis at a wavelength of 620nm as provided in NY/T 55-1987 *Determination of Amylose in Grains of Rice, Maize and Millet (GB/T 12087-2008)*.

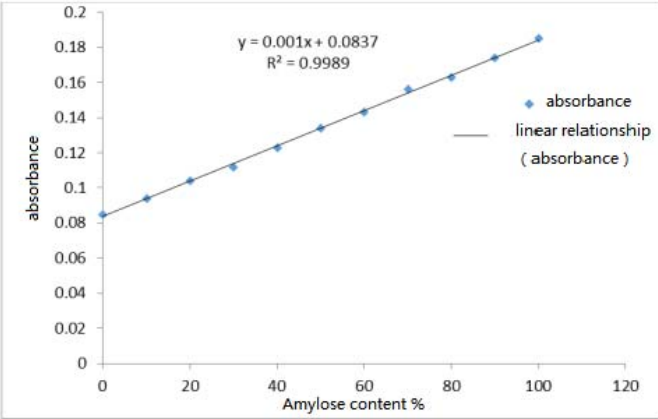


Figure 1: Standard curve of amylose content

(4) Determination of repose angle of different varieties of potato powder

Refer to the method proposed by Tian Xiaohong (Wang et al., 2016).

(5) Determination of water holding capacity of different varieties of potato powder

We weigh 1g of potato powder processed by different methods respectively, pour it into a centrifuge tube containing 25mL of distilled water, place it in the water bath at 25°C for oscillation for 1h, and then use the centrifuge to process the potato powder for 20min at a rotating speed of 4000r/min. After that, we take out the supernatant and weigh it.

$$\text{Water holding capacity} = \frac{\text{Mass of the water absorbed}}{\text{Sample mass}} \times 100\%$$

(6) Determination of WAI (WAI) and WSI (WSI) of different varieties of potato powder

We weigh 1.5g of potato powder sample of each variety, pour it into a centrifuge tube, add 18mL of distilled water, use a shaker to shake it for 0.5h, and then use the centrifuge to process the potato powder; for centrifugal parameters, we refer to the determination of water holding capacity. Take out the supernatant and pour it into the evaporating dish, place it in the drying oven for drying and then weigh the product, and at the same time determine the gel weight (Ji and Ding, 2000).

The calculation formula is as follows:

$$\text{WAI}(\%) = \frac{\text{Gel precipitation weight}}{\text{Dry weight of the sample}} \times 100$$

$$\text{WSI}(\%) = \frac{\text{Mass of the supernatant}}{\text{Dry weight of the sample}} \times 100$$

(7) Determination of viscosity of different varieties of potato powder

We weigh around 7g of potato powder sample and place it into a beaker, add 50mL of distilled water, fully shake it to make it mixed evenly and then conduct the viscosity determination (Xu, 2012).

(8) Determination of enthalpy in the differential scanning calorimetry

We take potato powder sample and distilled water at a ratio of 1:3. After mixing them well, we weigh about 5mg of sample and place it into the test container and determine the temperature, melting temperature differences and enthalpy variation throughout the whole process at the starting point, peak and ending point

under the conditions where the starting temperature is 25°C, the final temperature is 150°C and the temperature rise rate is 5°C /min (Shi et al., 2009).
(9) Determination of gelatinization degree of different varieties of potato powder
Refer to the method proposed by Xiong Yiqiang (Su et al., 2009; Zeng et al., 2011; Xiong, 2000).
(10) Determination with particle micrographs of different varieties of potato powder
We take trace amount of potato powder sample, add distilled water with 5 times dosage and mix them well into dilute starch milk, take trace amount of dry potato powder, place them onto the glass slide respectively, cover them with cover glasses, and observe them with an optical microscope at a magnification of 10X. We adjust the focus, take pictures and observe the micromorphology of different varieties of potato powder.

2. Result analysis

2.1 Particle size distribution of different varieties of potato powder

From the above four figures, we can see that the particle size distributions of the potato powder processed in different ways are different. The particle size of potato granules is the most widely distributed, ranging from 0.6 to 50, but it is more concentrated in the range from 2 to 5 and from 5 to 10, which accounts for 24.51% and 24.86% of total granule amount, respectively. The percentage of potato powder with a particle size of ≤0.5 and ≥44 is low, which is only about 0.5%. By contrast, the distributions of potato starch and milled potato powder are narrow and concentrated in the range of 0.5~5.0, especially in the range of 0.5~1.0 and 1.0~2.0, which account for 37.62% and 38.34%; potato powder with a particle size of ≤0.5 and ≥7 only accounts for about 1%. Due to the large size of potato flakes, the particle size is mostly concentrated in the range above 100.0.

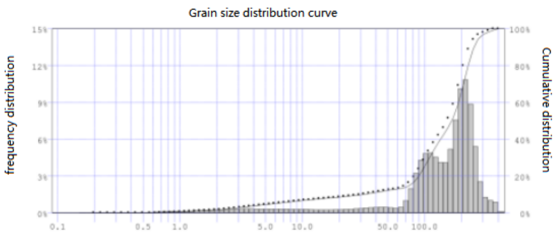


Figure 2: Particle size distribution map of potato flakes

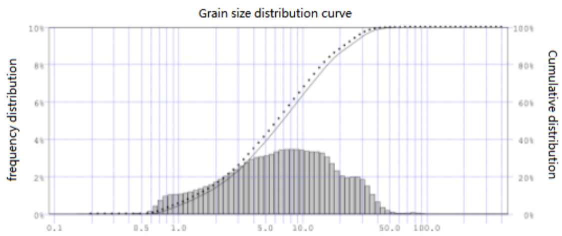


Figure 3: Particle size distribution map of potato granules

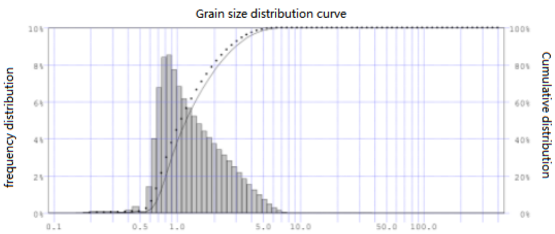


Figure 4: Particle size distribution map of potato starch

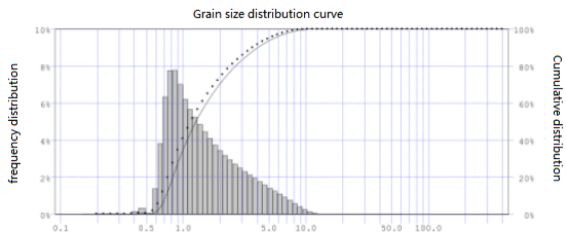


Figure 5: Particle size distribution map of milled potato powder

2.2 Result analysis on the physical indexes of potato powder with different particle sizes

Through the test, we obtain the standard curve of amylose and then conduct linear regression analysis on the graph. According to the regression equation $y=0.001x+0.0837$, we calculate the content of amylose in the potato sample. According to the data in Table 1, the amylose content in three varieties of potato powder is between 10%~25%, while the content of amylopectin is between 78%~90%.
The increase of heating level and intensity makes the friction and adhesion between particles decrease, further leading to lower adsorption capacity of the starch particles and smaller angle of repose. WSI and WAI reflect the degradation and absorption of the powder, respectively. The larger the WAI is, the greater the adhesion between and viscosity of the particles are (Li et al., 2014). As can be seen from Table 2, the WAI of potato flakes is the largest, while that of the potato starch is the smallest, so in the production and processing of potato products, potato starch is preferred as a raw material to reduce the viscosity of products (GB/T 15683-2008). WSI reflects the water solubility of potato powder. As can be seen from Table 2, WAI and WSI are negatively correlated – the higher the WAI is, the lower the WSI is, and vice versa. The water holding

capacity and WSI increase with the decrease in the heating intensity of the potato powder, while WAI increases with the increase of the starch heating intensity (Chen, 2008).

Table 1: Results of physical indexes of potato powder with different particle sizes

Group	Amylopectin (%)	Amylose (%)	Angle of repose (°)	Water holding capacity (%)	WSI (%)	WAI (%)
Potato flakes	83.75	16.25	31.47	4.28	2.78	314.59
Potato granules	87.65	12.35	23.63	2.88	2.03	342.90
Potato starch	79.60	20.40	37.37	6.83	3.03	270.22
Milled potato powder	78.40	21.60	37.95	7.50	3.19	287.44

2.3 Result analysis on the internal properties of potato powder with different particle sizes

Through the test, we find that the gelatinization degree is over 46.03% for milled potato powder, 52.67% for potato starch, over 64.35% for potato flakes, and up to over 74.60% for potato granules.

Table 2: Results of internal properties of potato powder with different particle sizes

Group	Gelatinization degree (%)	Viscosity	Moisture content (%)
Potato flakes	64.35	1121.33	7.36
Potato granules	74.60	1704.06	5.99
Potato starch	52.67	358.12	15.41
Milled potato powder	46.03	332.41	15.17

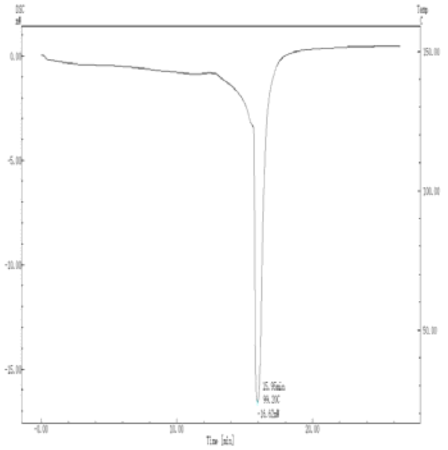
From the data analysis in Table 2, it can be seen that the viscosity of potato powder is positively correlated with the heating intensity and duration of the potato powder during the production process. The greater the heating intensity of the potato powder is and the longer the heating duration is, the larger the viscosity will be (Tian et al., 2010). The study also shows that the moisture content of potato flakes, potato granules, potato starch and milled potato powder is 7.36%, 5.99%, 15.41% and 15.17%, respectively.

2.4 Data analysis with Dsc

From the data in Table 3, it can be seen that in the whole DSC process, the total △H produced by potato starch is 218.04J/g, and the whole enthalpy change process of the potato starch is very long, with a temperature difference of 77.90°C. When the temperature reaches 53°C, the decreasing trend of enthalpy change becomes more apparent. When the temperature reaches 94.2°C, the whole process reaches its peak. In contrast, the initial temperature of potato granules is similar to that of potato starch, but the whole temperature span is short, with a temperature difference of 48.55°C, and the △H of the whole DSC process is much lower than that of potato starch, which is only 133.24J/g. The downward and upward trends in the whole process are more obvious than those of the potato starch. The T_0 of potato flakes is 85.57°C, much higher than that of the starch and granules, and the Tc is 112.31°C. The duration of the whole process is short and the temperature difference is not large - only 26.74 °C, but the △T also reaches 103.64J/g. T_0, Tp and Tc of milled potato powder are very close to those of potato starch, probably because no high-temperature heating method is used to dry powder in either process, causing no big change in the physical and chemical properties. Compared with those of potato starch, milled power and granules, the peak in the DSC curve of potato flakes is much more obvious, and the start and end of enthalpy change are shorter. From the thermodynamic characteristic parameters of the four varieties of potato powder in Table 3, the initial temperature of starch, granules and flakes gradually increases, and on the other hand, the enthalpy in the DSC curve decreases in turn.

Table 3: Data analysis with differential scanning calorimetry

Group	T_0 (°C)	Tp (°C)	Tc (°C)	Tc-T_0(°C)	△H(J/g)
Potato flakes	85.57	99.21	112.31	26.74	103.64
Potato granules	54.57	89.28	103.12	48.55	133.24
Potato starch	53.76	93.63	131.66	77.90	218.04
Milled potato powder	52.34	88.59	127.53	75.19	174.81



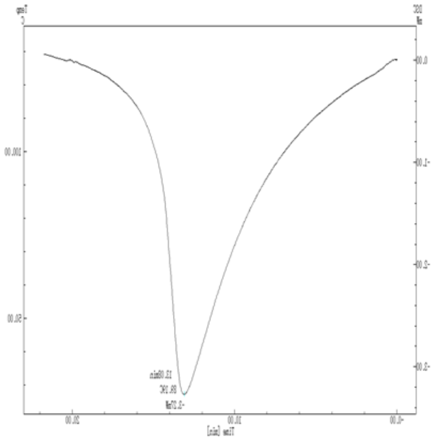
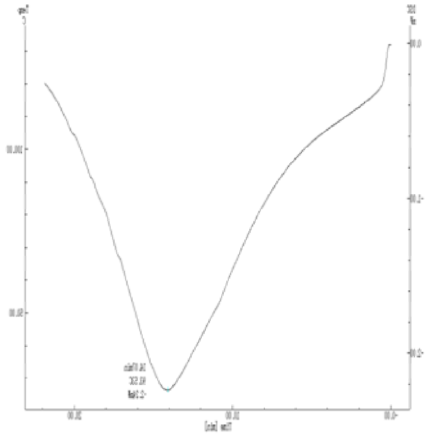


Figure 6: Potato flakes *Figure 7: Potato granules*



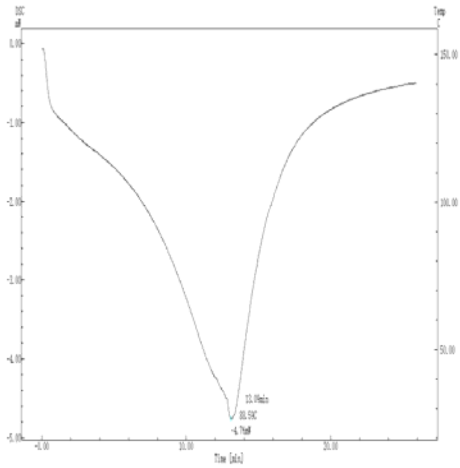
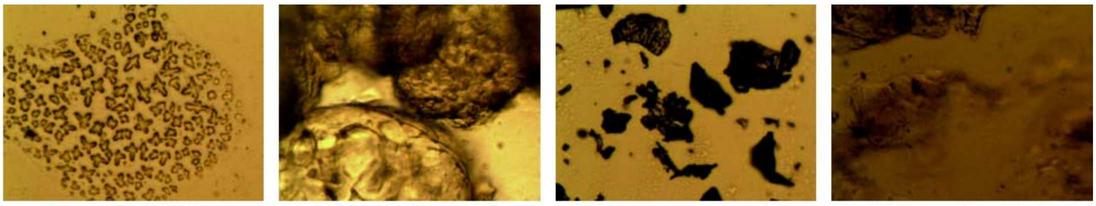


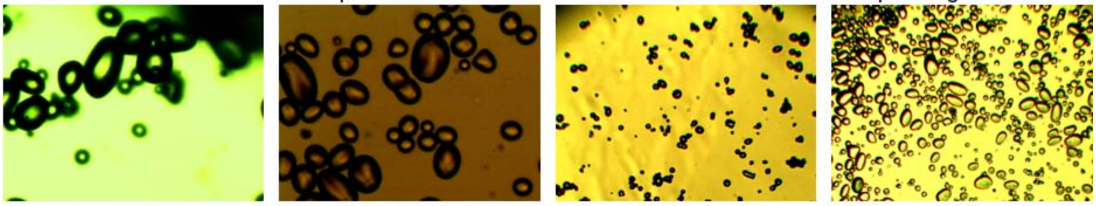
Figure 8: Potato starch *Figure 9: Milled potato powder*

2.5 Optical micrographs

Figure 10~17 are the photos of the four varieties of potato powder observed with the microscope at a magnification of 10X.



a. Dry potato flakes | b. Water-dissolved potato flakes | c. Dry potato granules | d. Water-dissolved potato granules



e. Dry potato starch | f. Water-dissolved potato starch | g. Dry milled potato powder | h. 17 Water-dissolved milled potato powder

Figure 10: Optical microscopic image of potato starch

From the figures, we can see that dry potato flakes are of leaf shape, on which there are a lot of cross-shaped marks. Water-dissolved potato flakes are highly soluble in water, so they look like fluffy spheres; dry potato granules show typical polygon potato powder shapes, and the water-dissolved granules have no obvious shapes; dry potato starch shows a relatively uniform ellipsoidal shapes, and after being dissolved in water, the morphology of starch is not obviously affected; the dry milled potato powder shows different sizes of ellipsoids, and after being dissolved in water, the shapes are a little expanded, so the observed particles are significantly larger than those before water is added. From the above figures, we can conclude that different processing methods have significant impacts on the properties of potato powder. Under different methods, the potato particles are damaged to different extents during production, and as a result, some starch forms are incomplete.

3. Conclusions

In summary, the different processing methods for potato powder have caused differences in its physical and chemical properties. In our test, we determine all physical and chemical indexes of the potato powder processed in different ways and obtain the following conclusions:

(1) The content of amylose in potato flakes is lower than those in other three varieties. The content of amylase in potato starch and milled potato powder is close. The surface characteristics of different varieties of potato powder cause macroscopic changes in the angle of repose. The angle of repose increases with the decrease of the potato powder particle size. The gelatinization degree and viscosity are related to not only the processing method for potato powder but also the moisture content in there.

(2) The water holding capacity and WSI decrease with the increase of the heating intensity of potato starch, while the WAI increases with the increase of the heating intensity, because during the processing of potato powder, due to heating and mechanical extrusion, the integrity of starch molecules are damaged, leading to the degradation of starch molecules and affecting the water absorption capacity and water holding capacity of potato powder particles.

(3) The thermal stability of potato powder increases with the decrease in the heating intensity.

Reference

Chen X., 2008. Arrowroot starch properties and application of, food science, 1-88. DOI: 10.7666/d.Y1277624-05-20.

GB/T 12087-2008, Starch moisture determination oven method.

GB/T 15683-2008, Determination of amylose content in Rice.

Ji H.W., Ding X.L., 2000. Method for separating potato amylose and amylopectin, Food Science and Technology, 6, 6-7. DOI: 10.13684/j.cnki.spkj.2000.06.004

Li F.L., 2012. Discussion on potato starch, Inner Mongolia Agricultural Science and Technology, 1, 131-134. DOI: 10.3969/j.jssn.1007-0907.2012.01.078

Li Z.W., Zhong Y.Y., Wu Q.M., Gao J., Liu X.X., Kang H.M., Guo D.W., Xue J.Q., 2014. Physicochemical properties of high amylose maize starch, Journal of Northwest A&F University (Natural Science Edition), 42(7), 53-60. DOI: 10.13207/j.cnki.jnwafu.2014.07.035

Peng J.J., Wu G., Yang Y.C., Xu K.Q., Zhao F.M., 2007. Production and application of potato granules and snowflakes powder, Science and Technology of Cereals, Oils And Foods, 15(4), 12-13. DOI: 10.3969/j.issn.1007-7561.2007.04.005

Shi H.X., Xiong Z., Fang H.Y., 2009. Starch properties analysis and application of, GUANGDONG CHEMICAL INDUSTRY, 36(3), 13-15. DOI: 10.3969/j.issn.1007-1865.2009.03.006

Su X.J., Xiong X.Y., Tan X.H., Wang K.Q., Cai L., 2009. Effect of irradiation on Malaysia raw potato starch saccharification efficiency, Bell potato industry and food security 2009.

Tian X.H., Li G.T., Zhang S.L., 2010. A probe into the method of measuring the natural repose angle of grain, GRAIN PROCESSING, 35(1), 68-71. DOI: 10.3969/j.issn.1007-6395.2010.01.019

Wang Y., Pan Z.C., Liang S.M., Yang Q.F., Li X.B., Bai J.M., Sui Q.J., 2016, Physicochemical properties of starch from 4 potato varieties, Guizhou Agricultural Sciences, 44(11), 24-28. DOI: 10.3969/j.issn.1001-3601.2016.11.005

Xiong Y.Q., 2000. Determination of gelatinization degree (degree of maturation) of feed starch, FEED INDUSTRY, 21(3), 000030-31. DOI: 10.3969/j.issn.1001-991X.2000.03.012

Xu Y.L., 2012. Study on viscosity of three kinds of potato starch and acetylated starch, Shaanxi University of Science and Technology, 5, 17-18. DOI: 10.7666/d.y2093787

Zeng F.K., Zhao X., Zhou T.H., Gao X.H., Gen Q.F., Liu G., 2011. Method for separating potato amylose and amylopectin, Modern Food Science & Technology, 27(12), 1466-1468. DOI: 10.3969/j.issn.1673-9078.2011.12.012