Chapter 10

The Effects of Processing Technology on Sweetpotato Starch Yield and Quality

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Abstract

Using the sweetpotato variety Xushu 18, three factors are observed by orthogonal design for there effect on extraction rate and quality of sweetpotato starch (SPS). The factors are: milling method of fresh sweetpotato, separating fineness method and precipitating method. By synthetic analysis, two sets of technologies were identified that could improve starch quality and extraction rate. To improve starch quality, the combination of saw tooth milling at 1000 revolutions/minute, separation using 120 size mesh and precipitation with sour liquid was found to have the best result. To increase starch extraction rate, the technology suggested is the combination of hammer mill in 4200 revolutions/minute, separation with 120 mesh and natural precipitation.

Key words: sweetpotato starch, processing technology, extract rate, quality, whiteness, protein content, ash content

Introduction

Sweetpotato is an important root crop and biological resource. In the new Sichuan Province of China (excluding Chongqing munipality), area planted to sweetpotato totals 960,000 hectares (14,360,000 *mu*). Total production is 17.72 million tons accounting for 16 per cent of the whole country's total output. Sweetpotato cropland is located mainly in marginal hilly lands.

In the last 10 years, peasant households engaged in the processing of sweetpotato starch, which consequently improved their income and the local economy. But due to the use of traditional methods, extraction rate and quality of starch were low (Zongfu and Liping; Meng 1996). Processing enterprises and peasant households were in dire need of improved small-scale equipment and techniques. The development of starch processing industry would also benefit enterprises and industries using starch as raw materials by providing them with high quality starch (Liping 1996). Thus, serious attention must be given to the development of small equipment and package of processing technology for sweetpotato starch (SPS).

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In this study, the orthogonal test on processing technologies that affect the quality and extraction rate of starch was conducted. A complete set of processing technologies for SPS was also identified in order to contribute to the development of sweetpotato starch processing industry.

Materials and methods

Sweetpotato raw material

The sweetpotato variety Xushu 18 was harvested in November 12, 1999 in Santai County, Sichuan, China, was used in the analysis of starch extraction.

Main experiment equipment

The washing, grinding and separating machine was the Yuntai-400 and Yuntai-500 models manufactured in Santai County, Sichuan. The main analyzer was an electro-thermal dryer (made in Chengdu City, Sichuan). Other equipment included a KDY928 nitrogen analyzer (made in Siping City, China), ashing stove, WGB-whiteness detector.

Preparation of starch sample

The results of orthogonal test of processing technology of sweetpotato starch in 1998 were used. This involved the following steps:

The amount of water was weighed for cleaning sweetpotato. The water amount for separating was 1000 liters of water per 200 kg sweetpotato root. The precipitation time was 8-12 hours.

An orthogonal test was made with nine trials (Sichuan Agricultural University *et al*. 1993), which included three combinations of technologies on milling method, separating fineness and precipitation method. Each treatment was repeated three times (Tables 1 and 2).

The extraction process of sweetpotato starch was done as follows: Fresh sweetpotato (200 kg) was washed in1000 liters of water. Then the roots were milled using either the hammer mill method at 3200 r/min. or 4200 r/min, or saw tooth milling at 1000 r/min. Then the solution was passed through one of three mesh sizes (80, 120 or 200 mesh) to separate the starch from solids in the solution. The starch solution was then left to precipitate for 8-12 hours, either by natural, flow grow or sour liquid technique. Finally, the starch was dried, weighed and evaluated for quality.

Determination of sample

Extraction rate of starch. According to " the national standard of industrial SPS (3.2 of QB.3-92) (Chinese Light Industry Association 1992), water content of starch is converted to the standard 15% moisture of the wet weight of starch. The ratio of this to the weight of fresh sweetpotato is the extraction rate of starch.

Water content of starch. The dry method by oven under normal pressure (GB 12309-90,4.3.1) was used. This involved drying for 40 minutes at 131±2°C, and then weighing the sample.

Determination of crude protein. This adopted the macro Kjeldahl's method using the instrument KDY 928 nitrogen analyzer.

Determination of ash. The ash content was determined by the dry analysis (GB 12309-90, 4.3.5).

Determination of whiteness. The fluorescence analysis was applied with the instrument WGB-whiteness analyzer.

Sensory check.

a. Whiteness check: 20 g of starch sample was put in a beaker, added with 100 ml of water, and heated on the electric stove while stirring. When it was gelatinized completely, the whiteness and odor were evaluated using a scale of 1-15. Starch with white color and no peculiar odor gained the highest score.
b. Foreign matter check: 20 g of sample was placed in a beaker, added with 200 ml of water, stirred evenly and then left for 30 minutes to settle. The bottom precipitation and the muddy extent of upper liquid were observed. On a scale of 1-15, starch with the least foreign matter got the highest score.

Results and discussion

Extraction rate of sweetpotato starch

In the different processing technologies, the extraction rate of samples ranged from 15 .0 to 16.6% (Table 3). The analysis of variance showed that the effects of the three processing factors, namely milling method, separating fineness and precipitating method all reached highly significant levels (Table 4). Among milling methods, the highest extraction rate of starch was obtained by hammer milling at 4200 r/min followed by hammer milling at 3200 r/min and saw tooth milling at 1000 r/min. Starch extraction rate went down as separating mesh size increased. The highest extraction rate was observed in the separation with 80 mesh, followed by 120 mesh, and the lowest was with 200 mesh. More fine fibers, foreign matters and less big starch grains were removed with larger separating mesh.

In the precipitating method, the highest extraction rate was observed in natural precipitation, followed by the sour liquid precipitation and the flow groove precipitation. The sour liquid precipitation separated thoroughly the foreign matter in starch and removed the yellow flour and impurity. The water flowing in the flow groove precipitation method washed away impurities but took out some starch as well.

The results of Duncan's test on starch extraction rate in various treatments showed significant differences among treatments. The highest rate was obtained by a combination of hammer break in 4200 r/min, separating in 120 mesh and natural precipitation.

Content of crude protein (CPC) and ash in SPS

In this study, the crude protein content (CPC) in SPS were 0.36%-0.39% (Table 6). The milling method, precipitating mesh and precipitating method affected the CPC of SPS significantly (Table 7). The most influential factor was milling method with the highest content of crude protein obtained by hammer milling at 3200 r/min, separation with 120 mesh combined with saw tooth milling or by hammer milling at 4200 r/min. The Duncan's test showed the same result (Table 8). In this study, the protein content in five treatments was higher than the national standard of 0.40 percent (Chinese Light Industry Association 1992).

The results of ash content in different treatments were 0.32-0.96%. The analysis of variance showed that the effects of precipitating and milling methods were significant (Tables 9 and 10). The higher ash content appeared in hammer break method, but the sour liquid treatment reduced this content. The Duncan's test showed the same result (Table 11). Among various treatments, the lowest content of ash and crude protein was obtained through a combination of planning shed break, separation with 120 mesh and sour liquid precipitation. According to the trade standard of potato starch ratified by the former National Light Industry Ministry and published in 1993, ash content in grades 1 and 2 of starch must be ≤ 0.6 percent and ≤ 0.9 percent. In later years, the developing noodle industry and international market required ≤ 0.3 percent of ash content in SPS (Qingding 1995). Many factories encountered the problem of high ash content. Thus, it is important to strongly encourage cleaning of material, use of sand remover and adoption of proper precipitating method and separating mesh.

Whiteness and sensory quality of SPS

The whiteness determined in this study was 69.2%~ 82.4%. The highest was obtained in the sample treated with sour liquid (Table 12).

The whiteness, odor and impurity of starch were evaluated. The results showed that the precipitating method, separating mesh and milling method all affected the quality of starch. Among the precipitating methods, the quality of starch treated by sour liquid was better than that starch precipitated by flow groove and natural precipitation. Among the milling methods, saw tooth milling was better than hammer milling. With the separating fineness, 120 and 200 meshes were better than 80 mesh (Tables 13 and 14). The results of Duncan's test are shown in Table 15. SPS with better quality was produced by a technology combination of separation with 120 mesh, sour liquid precipitation and saw tooth milling.

Conclusions

1. In the SPS processing, the highest extraction rate was by hammer milling at 4200 r/min, separation with 80 mesh and natural precipitation.

2. Separation with 120 mesh, saw tooth milling and precipitation with sour liquid gave the smallest amount of protein and ash content.

3. The sour liquid treatment and more than 120 mesh of separating fineness raised the whiteness and odor quality of SPS significantly.

4. Based on the three factors affecting extraction rate and quality of SPS by synthetic analysis, two effective sets of technology packages were identified. First, to improve starch quality, the combination of saw tooth milling, separation with 120 mesh and precipitation with sour liquid should be adopted. Second, to increase extraction rate of starch, it is recommended to use a combination of hammer milling at 4200 r/min, separation with 120 mesh and natural precipitation.

The development of the SPS processing industry depends on the improvement of extraction rate and quality of starch. But when starch processing factories with small-sized equipment select the processing technology, the problem is that extraction rate was raised but the starch quality was poorer, or the quality was improved but the extraction rate declined. To improve both attributes simultaneously, future studies should focus on the development of a complete package of technologies that would include not only the equipment for starch processing but also improved processing technologies.

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Table 1. Three types of technologies tested for various steps in starch processing: milling type, separating mesh, precipitating method

Test factor	1	2	3
Milling type	hammer, 320 r/m	Saw tooth, 1000 r/m	hammer, 1200 r/m
Separating mesh	80 mesh	120 mesh	200 mesh
Precipitating method	natural precipitation	precipitation by flow groove	precipitation with sour liquid

Table 2. Orthogonal test of three factors $L_9(3^4)$ of milling type, separating mesh size and precipitating method

Test no.	1 Milling type	2 Separating mesh	3 Precipitating method
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Table 3. Extraction rate of SPS using different processing technologies

Exp.no	1 Milling	2 Mesh	3 Precipitation	Trial Repetition 1	2	3	Ti	Xi
1	1	1	1	11.93	12.01	12.92	36.86	12.29
2	1	2	2	10.24	10.57	10.37	31.18	10.39
3	1	3	3	12.09	13.38	11.50	36.97	12.32
4	2	1	2	13.41	13.23	12.80	39.44	13.15
5	2	2	3	10.55	10.22	9.69	30.46	10.15
6	2	3	1	11.26	11.10	11.34	33.70	11.23
7	3	1	3	14.58	15.03	14.91	44.52	14.84
8	3	2	1	16.39	16.88	16.50	49.77	16.59
9	3	3	2	11.20	11.36	11.63	34.19	11.40
T1	105.01	120.82	120.33	111.65	113.78	111.66		
T2	103.60	111.41	104.81					
T3	128.48	104.86	111.95					
Rx	24.88	15.96	15.52				T=337.09	

Table 4. Analysis of variance of extract rates for SPS

Variable resources	DF	SS	MS	F
Among blocks	2	0.3307	0.1654	0.8508
Among treatments	8	13.299	13.299	68.41**
Milling method	2	21.70	21.70	111.63**
Separating mesh	2	7.15	7.15	36.78**
Precipitating method	2	6.705	6.705	34.49**
Error 1	2	17.64	17.64	>1
Error 2	16	0.1944	0.1944	

$F_{0.05\ (2,16)}$ =3.63 $F_{0.01\ (2,16)}$=6.23 $F_{0.05(8,16)}$=2.59 $F_{0.01(8,16)}$=3.89

Table 5. Duncan's test on extraction rate of SPS

Treatment no.	Mean of Extract rate	Significance of variance	
		5%	10%
8	16.59	a	A
7	14.84	b	B
4	13.15	c	C
3	12.32	d	C D
1	12.29	d e	C D
9	11.40	e	C D
6	11.23	e f	C D
2	10.39	f	D
5	10.15	g	D

Table 6. Crude protein content of SPS

Exp. No.	1	2	3	Trial Repetition (Protein Content, %)			Ti	Xi
				1	2	3		
1	1	1	1	0.94	1.00	1.03	2.97	0.99
2	1	2	2	0.93	0.88	0.78	2.59	0.86
3	1	3	3	1.22	144	1.52	4.18	1.39
4	2	1	2	0.49	0.28	0.34	1.11	0.37
5	2	2	3	0.28	0.31	0.48	1.67	0.36
6	2	3	1	0.38	0.49	0.59	1.46	0.49
7	3	1	3	0.60	0.56	0.28	1.44	0.48
8	3	2	1	0.36	0.53	0.28	1.17	0.39
9	3	3	2	0.20	o.44	0.43	1.07	0.36
T1	9.74	5.52	5.60	5.40	5.93	5.73		
T2	3.64	4.83	4.77					
T3	3.68	6.71	6.69					
Rx	6.10	188	1.92					

Table 7. Analysis of variance of protein content of SPS

Variable Resource	DF	SS	MS	F
Inter-block	2	0.016	0.008	0.533
Inter-treat	8	3.253	0.407	27.133**
Milling method	2	2.739	1.369	91.267**
Separating mesh	2	0.201	0.101	6.733**
Precipitating method	2	0.206	0.103	6.877**
Error 1	2	0.107	0.053	3.533
Error 2	16	0.242	0.015	

$F_{0.05(2,16)}=3.63$ $F_{0.01(2,16)}=6.63$ $F_{0.05(8,16)}=2.59$ $F_{0.01(8,16)}=3.89$

Table 8. Duncan's test on protein content (PC) of SPS

Treat No.	Mean of PC (%)	Variation Significance	
		5%	10%
3	1.39	A	A
1	0.99	b	B
2	0.86	b c	B C
6	0.49	c	C
7	0.48	c	C
8	0.39	c	C
4	0.37	c	C
9	0.36	c	C
5	0.36	c	C

Table 9. Ash content (%) of SPS using different processing technologies

Col. No. Exp. No.	1	2	3	Trial Repetition 1	2	3	Ti	Xi
1	1	1	1	0.944	0.918	1.02	2.882	0.961
2	1	2	2	0.914	0.760	0.927	2.657	0.884
3	1	3	3	0.882	0.593	0.853	2.328	0.776
4	2	1	2	1.00	0.518	0.774	2.492	0.831
5	2	2	3	0.314	0.345	0.290	0.949	0.316
6	2	3	1	0.784	0.808	0.868	2.460	0.820
7	3	1	3	1.04	0.52	0.760	2.320	0.773
8	3	2	1	1.086	0.837	0.902	2.825	0.942
9	3	3	2	0.688	0.947	0.876	2.511	0.837
T1	7.861	7.694	8.167	7.702	6.246	7.47		
T2	5.901	6.425	7.654					
T3	7.656	7.299	5.597					
Rx	1.96	1.269	2.570					

$F_{0.05(2,16)}$=3.63 $F_{0.01(2,16)}$=6.63 $F_{0.05(8,16)}$=2.59 $F_{0.01(8,16)}$=3.89

Table 10. Analysis of variance of ash content of SPS

Variable Resource	DF	SS	MS	F	Relative F to merge error
Inter-block	2	0.136	0.068	3.579	4*
Inter-treat	8	0.871	0.109	5.737	6.412*
Milling method	2	0.358	0.179	9.421	10.529**
Separating mesh	2	0.094	0.047	2.474	2.765
Precipitating method	2	0.411	0.206	10.842	12.118**
Error 1	2	0.008	0.004	<1	
Error 2	16	0.301	0.019		
Merge error	18	0.309	0.017		

$F_{0.05(2,18)}$=3.55 $F_{0.01(2,18)}$=6.01 $F_{0.01(8,18)}$=3.71

Table 11. Duncan's test on ash content of SPS

Treat. No.	Mean of Ash (%)	Variation Significance 5%	Variation Significance 1%
1	0.961	a	A
8	0.942	a	A
2	0.884	a	A
9	0.837	a	A
4	0.831	a	A
6	0.820	a	A
3	0.776	a	A
7	0.773	a	A
5	0.316	b	B

Table 12. Whiteness of SPS using different processing technologies

Exp. No.	1	2	3	4	5	6	7	8	9
Whiteness (%)	69.2	72.6	77.3	72.9	82.4	74.5	74.9	76.5	73.7

Table 13. Sensory evaluation of SPS using different processing technologies

	1	2	3	Trial Repetition				
Exp. No.				1	2	3	Ti	Xi
1	1	1	1	5.19	6.01	5.94	17.14	5.71
2	1	2	2	7.22	7.97	7.91	23.10	7.70
3	1	3	3	8.13	9.57	9.13	27.33	9.11
4	1	1	2	9.95	10.20	9.96	29.93	9.98
5	2	2	3	13.22	13.05	12.95	39.22	13.07
6	2	3	1	11.05	10.71	10.50	32.26	10.75
7	2	1	3	10.64	10.56	10.72	31.92	10.64
8	3	2	1	10.58	11.03	10.84	32.45	10.82
9	3	3	2	10.75	11.12	9.03	30.90	10.30
T1	67.57	78.99	81.85	87.23	90.04	86.98		
T2	101.41	94.77	83.93					
T3	95.27	90.49	98.47					

Table 14. Analysis of variance of sensory evaluation of SPS

Variable Resource	DF	SS	MS	F
Inter-block	2	0.65	0.33	1.57
Inter-treat	8	105.69	13.21	62.96**
Milling method	2	72.25	36.13	172.04**
Separating mesh	2	14.80	7.40	35.24**
Precipitating method	2	18.23	9.12	43.43**
Error 1	2	0.65	0.33	>1
Error 2	16	3.35	0.21	
Merge error				

$F_{0.05(2,16)}=3.63$ $F_{0.01(2,16)}=6.23$ $F_{0.05(8,16)}=2.59$ $F_{0.01(8,16)}=3.89$

Table 15. Duncan's test of sensory quality of SPS

Treat No.	Mean of Test Indexes	Significance of Variation	
		5%	10%
5	13.07	a	A
8	10.82	b	B
6	10.75	b c	B C
7	10.64	b c	B C
9	10.30	b c	B C
4	9.98	c	B C
3	9.11	d	C
2	7.70	e	D
1	5.71	f	E