



Relationship between Quality Traits and Ethanol Fermentation of Sweetpotato

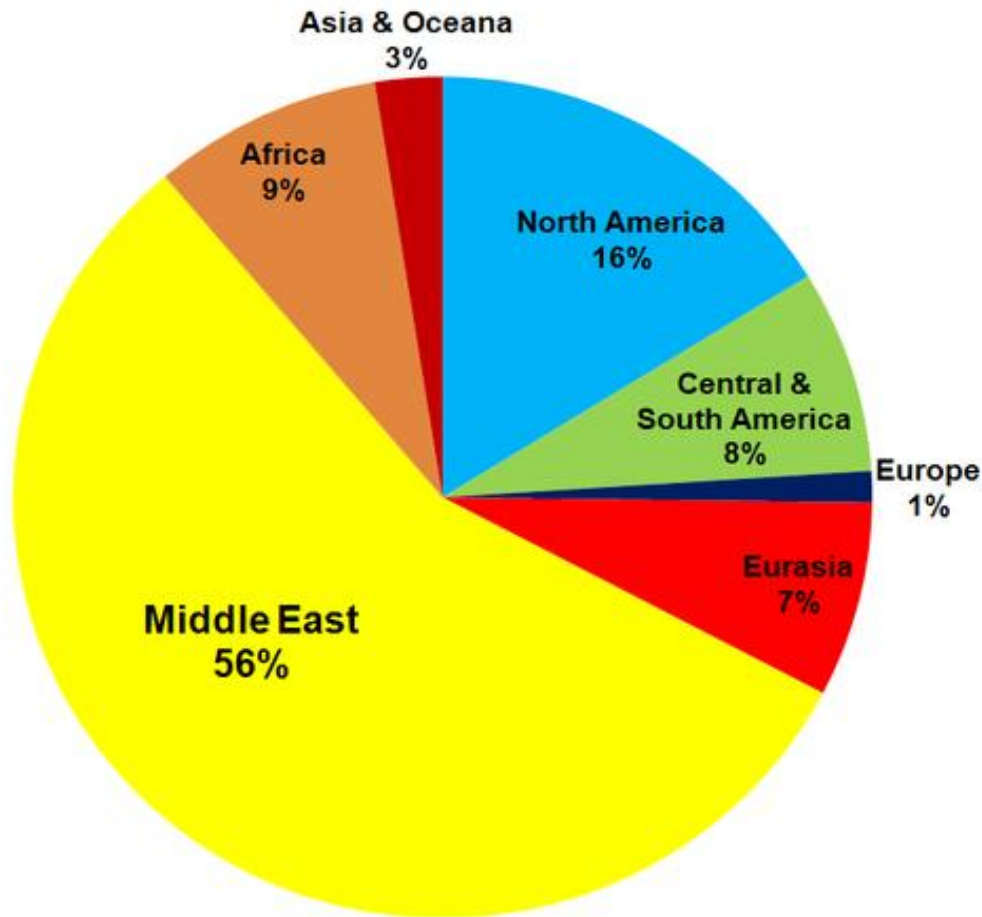
SUN Jian, SRI, CAAS

18 September 2012, Jeju City, Korea



Background

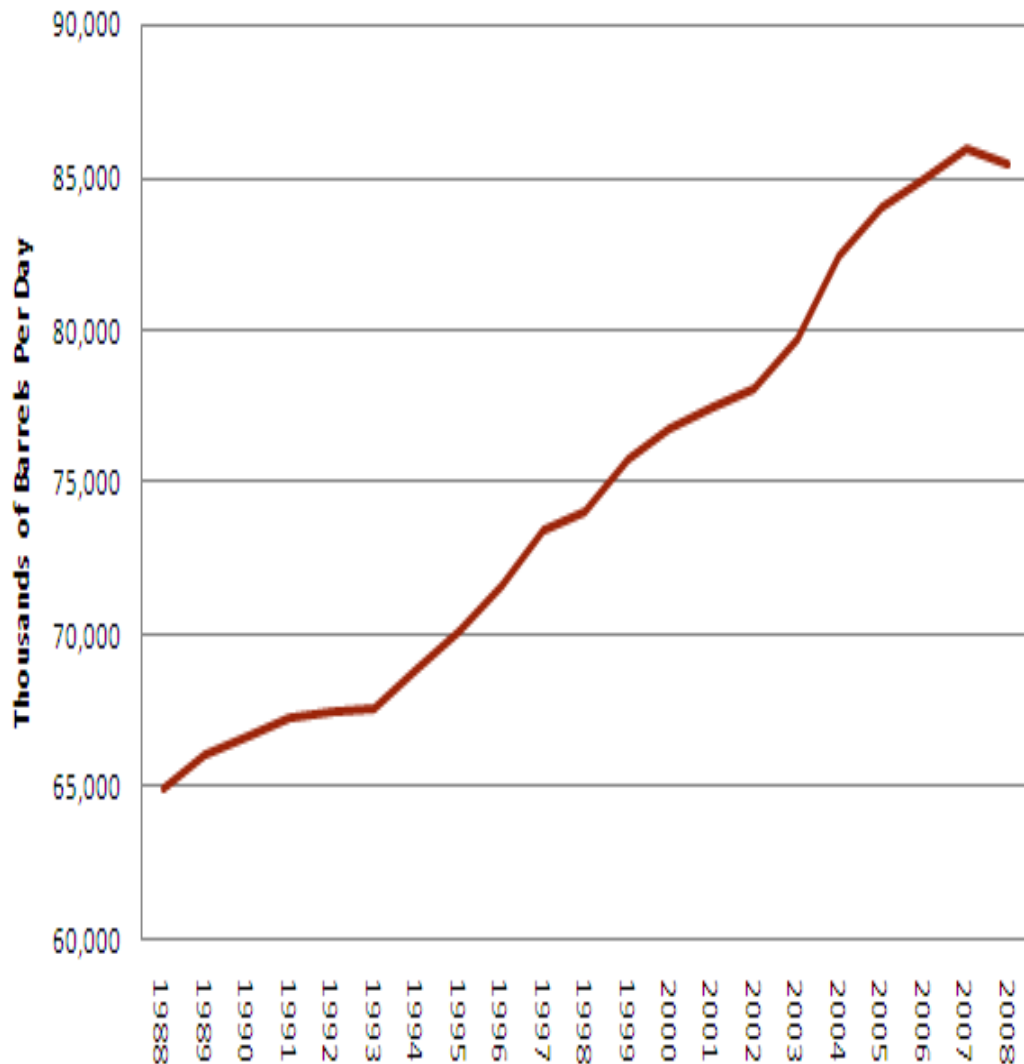
World Oil Reserves



Data source: US Energy Information Administration from Oil and Gas Journal (2007)
Oil includes crude oil and condensate

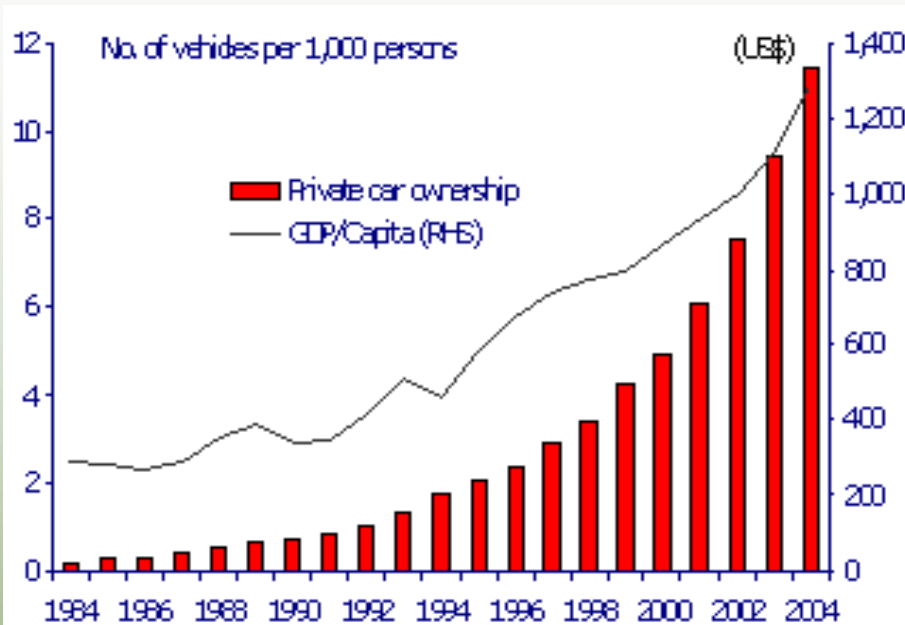
- The world's proved oil reserves were about 168.6 billion tons.
- Middle East was 94.4 billion tons.

World oil consumption



The service life of oil is about 40 years!!!

Environmental pollution was serious



Ranking	Country	2007 Total Vehicle Sales
1	U.S.A.	16,460,000
2	China	8,791,500
3	Japan	5,353,648
4	Germany	3,482,279
5	Russia	2,990,000
6	U.K.	2,799,620
7	Italy	2,774,137
8	France	2,584,035
9	Brazil	2,200,000
10	Spain	1,939,298

(in unit)



- Car amounts had been more than 5 million cars each year.
- Automobile emission has become the main pollution of city.



Fuel ethanol development situation in the United States

Using corn as raw materials

In 2005: 3.9 billion gallons (14.7 billion liters)

In 2006: 4.8 billion gallons (18.1 billion liters)

In 2010: 7.5 billion gallons (28.4 billion liters)

In 2050: 290 billion gallons (1.1 trillion liters)

The ratio of energy output/input is very low, only 1.34



Fuel ethanol development situation in Brazil

Using sugar cane as raw materials

- 2.7 million hectares sugar cane was planted In 2004, and it had produced 16.4 billion litres ethanol.
- 320 ethanol processing factories had been builded, had processed more than 430 million tons sugar cane , produced 30 million tons sucrose and 18 billion litres ethanol each year.

The ratio of energy output/input is 8.



Fuel ethanol development situation in China





Sweetpotato traits as starchy raw material

- China is by far the largest producer of sweetpotato in the world, accounting for 80 percent of global production.
- Sweetpotato is the fourth major crop only behind rice, wheat, and corn.
- Sweetpotato is an important crop used as food, feed, and industrial raw material.
- It will play a more important role in the course of biological energy development, due to the high starch yield.



Advantage of sweetpotato: **high output per unit area**

Crops	Planting cycle /m	Yield /(t/ha)	Starch content /%	Starch yield /(t/ha)	Ethanol yield /(t/ha)	Ethanol yield /(t/ha/y)
Sweet potato	5	22.5	20	4.5	2.25	5.40
Cassava	10	22.5	22	4.9	2.48	2.97
Corn	3	4.9	64	3.2	1.58	6.30



Advantage of sweetpotato: **low cost** in raw material

Item	Starch content /%	Raw material consumption /(t/t ethanol)	Raw material price /(\$ /t ethanol)
Sweet potato	20	10	316
Cassava powder	70	2.8	407
Corn	66	3	475



Nutrient content and ethanol fermentation



Nutrient content of sweetpotato powder

Variety	Starch /%	Reduced sugar/%	Soluble sugar /%	Protein /%
Suyu303	56.88	11.46	13.49	4.66
Xushu27	66.68	9.00	7.86	3.37
Ningshu43-5	55.38	13.56	14.20	5.07
Luoshu96-6	65.22	5.80	10.15	5.49
Shangshu056-3	65.19	8.44	9.53	3.73
Xushu508	64.14	7.40	10.06	4.27
Xushu24	63.65	10.54	11.33	4.06
Xushu037809	62.01	6.34	9.70	6.67
Xushu22	56.14	7.41	11.35	7.02
Nongda6-2	65.21	5.34	9.09	4.70
Xushu25	63.37	5.09	10.97	5.78

Ethanol yield of fresh sweetpotato

Variety	Ethanol yield/(%)	Sig.	
		0.05	0.01
Xushu22	13.60 ± 0.080	a	A
Nongda6-2	12.66 ± 0.058	b	B
Xushu24	12.29 ± 0.023	bc	BC
Luoshu96-6	12.18 ± 0.039	bc	BC
Xushu25	11.98 ± 0.020	c	C
Shangshu056-3	11.67 ± 0.049	d	D
Xushu508	11.40 ± 0.053	e	E
Xushu27	11.09 ± 0.026	f	F
Ningshu43-5	9.54 ± 0.052	g	G



Ethanol yield of sweetpotato powder

Variety	Ethanol yield/(%)	Sig.	
		0.05	0.01
Mixuan1	36.76 ± 0.078	a	A
Xushu25	35.24 ± 0.050	b	B
Lizixiang	34.44 ± 0.050	c	C
Xushu036909	34.32 ± 0.028	cd	CD
Lvshu02	34.15 ± 0.085	d	D
Yanshu252	33.71 ± 0.064	e	E
Jishu17-4	32.76 ± 0.078	f	F
Qinshu506	31.42 ± 0.042	g	G
Xushu033404	30.03 ± 0.035	h	H



Correlation between nutrient content and ethanol yield of fresh sweetpotato

Item	Dry matter	Starch	Protein	Soluble sugar	Reduced sugar	Ethanol yield
Dry matter	1.000					
Starch	0.934**	1.000				
Protein	0.586	0.298	1.000			
Soluble sugar	-0.029	-0.293	0.532	1.000		
Reduced sugar	-0.701*	-0.688**	-0.487	0.222	1.000	
Ethanol yield	0.842**	0.671*	0.714*	0.136	-0.536	1.000

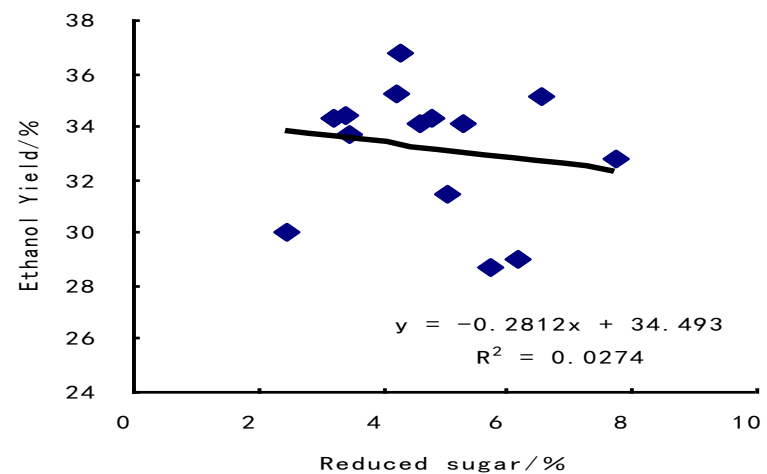
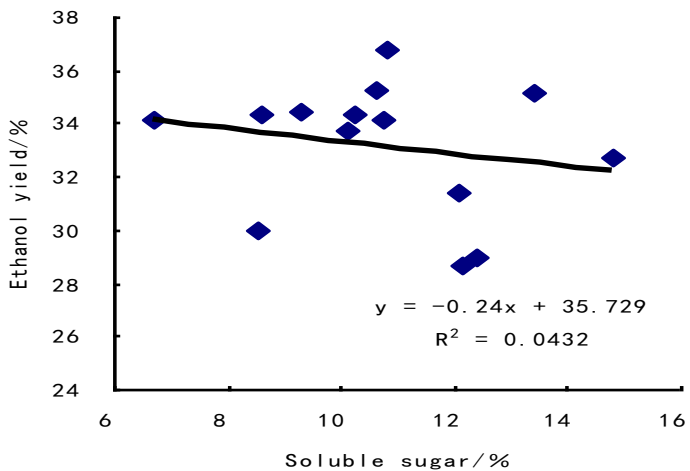
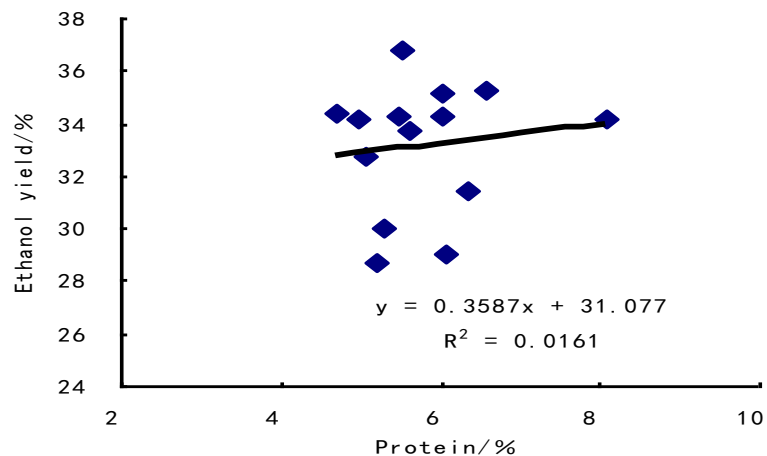
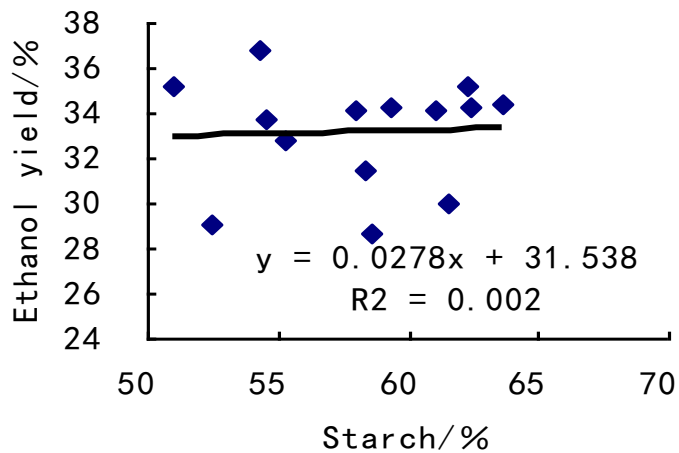


Correlation between nutrient content and ethanol yield of sweetpotato powder

Item	Starch	Protein	Soluble sugar	Reduced sugar	Ethanol yield
Starch	1.000				
Protein	0.074	1.000			
Soluble sugar	-0.627*	-0.339	1.000		
Reduced sugar	-0.566 *	0.022	0.824**	1.000	
Ethanol yield	0.046	0.134	-0.212	-0.164	1.000



Linear analysis





Multiple regression analysis

Variance analysis

Item	Sum of squares	df	Mean square	F	Sig.
Regression	3.567	3	1.189	7.237	0.015 ^a
Residual	1.150	7	0.164	—	—
Total	4.718	10	—	—	—



Multiple regression analysis

Regression coefficient and significant test

Item	Unstandardized coefficients		Standardized coefficients	t	Sig.
	B	Std.error	Beta		
Constant	2.086	2.045	—	1.020	0.342
Starch(X_1)	0.162	0.068	0.617	2.396	0.048
Protein(X_2)	1.064	0.365	0.623	2.912	0.023
Reduced sugar(X_4)	0.248	0.365	0.192	0.681	0.518

Note: dependent variable is ethanol production (Y) .



Conclusion

- Ethanol yield was significantly positive correlation with dry matter content ($P < 0.01$), starch ($P < 0.05$) and protein ($P < 0.05$) of fresh sweetpotato.
- Correlation between ethanol yield and quality traits of sweetpotato powder was not significant.
- Consequently, dry matter content and starch could be used to evaluate the ethanol yield of sweetpotato.



Amylose content, starch pasting and ethanol fermentation



Starch content and AC of sweetpotato from different variety

Variety	Dry matter (%)	Starch (%)	Amylose(%)
Fuxushu 20	38.05 ± 0.17A	26.65 ± 0.16 A	15.43 ± 0.61a
Xushu 4401	36.46 ± 0.09B	25.53 ± 0.09 B	14.28 ± 0.40bc
Zhenghong 22	36.37 ± 0.64B	25.47 ± 0.25 B	10.84 ± 0.14hi
Luoshu 96-6	35.53 ± 0.23BC	24.88 ± 0.06 B	14.96 ± 0.23ab
Yanshu 24	35.26 ± 0.24C	24.69 ± 0.13 BC	13.42 ± 0.59cd
Shangshu 056-3	34.03 ± 0.13D	23.83 ± 0.54 CD	12.90 ± 0.29de
Xushu 29	32.58 ± 0.44E	22.82 ± 0.49 E	12.53 ± 0.42ef
Nongda 6-2	32.49 ± 0.45E	23.22 ± 0.57 DE	11.80 ± 0.28fg
Xushu 24	32.43 ± 0.18E	22.71 ± 0.29 E	11.69 ± 0.14fgh
Luoxushu 9	32.09 ± 0.08E	22.47 ± 0.10 E	9.62 ± 0.42j
Xushu 28	30.52 ± 0.29F	21.38 ± 1.06 F	11.36 ± 0.51gh
Xushu18	29.53 ± 0.13G	20.68 ± 1.04 FG	10.46 ± 0.28ij
Xushu 508	28.51 ± 0.20H	19.96 ± 0.25 GH	9.63 ± 0.26j



Characteristic values of RVA profile of starch in different sweetpotato varieties

Variety	PKV(cP)	HPV(cP)	BDV(cP)	CPV(cP)	SBV(cP)	CSV(cP)	PT(°C)
Fuxushu 20	4780 ± 13c	2072 ± 44a	2708 ± 11def	3155 ± 71a	-1625 ± 42g	1083 ± 45b	76.45 ± 0.64a
Xushu 4401	3296 ± 28h	962 ± 58fg	2334 ± 48g	1563 ± 89hi	-1733 ± 60f	601 ± 28fgh	74.95 ± 1.34ab
Zhenghong 22	5737 ± 52a	2001 ± 16a	3736 ± 51a	3196 ± 27a	-2541 ± 74a	1195 ± 84a	74.90 ± 1.22ab
Luoshu 96-6	3045 ± 64i	701 ± 22i	2344 ± 62g	1248 ± 68j	-1797 ± 14ef	547 ± 49hi	73.45 ± 0.64bc
Yanshu 24	5155 ± 71b	1888 ± 40b	3267 ± 95b	2836 ± 51b	-2319 ± 19b	948 ± 11c	74.80 ± 1.13ab
Shangshu 056-3	3950 ± 70g	1274 ± 54de	2676 ± 11ef	1967 ± 47ef	-1983 ± 24c	693 ± 42f	74.90 ± 1.27ab
Xushu 29	3032 ± 45i	899 ± 37gh	2133 ± 47h	1463 ± 39i	-1569 ± 43g	564 ± 45ghi	73.40 ± 0.56bc
Nongda 6-2	4634 ± 45d	1776 ± 54c	2858 ± 32d	2679 ± 17bc	-1953 ± 66c	903 ± 42cd	74.90 ± 1.27ab
Xushu 24	3864 ± 61g	1260 ± 65de	2604 ± 56f	1886 ± 71fg	-1988 ± 10c	626 ± 37fgh	74.85 ± 1.20ab
Luoxushu 9	4118 ± 25f	1335 ± 49d	2783 ± 38de	2183 ± 42d	-1935 ± 16cd	848 ± 21de	74.95 ± 1.34ab
Xushu 28	4378 ± 10e	1282 ± 56de	3096 ± 13c	2082 ± 15de	-2296 ± 16b	800 ± 56e	74.15 ± 0.21abc
Xushu18	4410 ± 14e	1764 ± 57c	2646 ± 65ef	2570 ± 57c	-1840 ± 42de	806 ± 48de	73.40 ± 0.56bc
Xushu 508	4001 ± 14fg	1328 ± 40d	2673 ± 10ef	2182 ± 57d	-1819 ± 55ef	854 ± 43cde	72.60 ± 0.85bc



The characteristic values of ethanol fermentation in different sweetpotato varieties

Variety	Ethanol yield(%)	Fermentation efficiency(%)	Fermentative strength(g .L ⁻¹ .h ⁻¹)	Fermented mash viscosity(Pa.s)
Fuxushu 20	7.64 ± 0.21ab	73.85 ± 2.94bcd	3.18 ± 0.12ab	732.00 ± 42.42b
Xushu 4401	7.90 ± 0.28a	68.71 ± 0.57cde	3.29 ± 0.21a	7.32 ± 0.28d
Zhenghong 22	6.61 ± 0.08cdefg	66.64 ± 0.28de	2.75 ± 0.13bcde	84.30 ± 5.66d
Luoshu 96-6	7.32 ± 0.35abc	78.84 ± 3.36b	3.05 ± 0.22abc	2.84 ± 0.28d
Shangshu 056-3	7.14 ± 0.29abcd	77.98 ± 4.58b	2.98 ± 0.23abcd	4.33 ± 0.47d
Xushu 29	6.20 ± 0.94efg	72.53 ± 0.61bcde	2.58 ± 0.43def	681.00 ± 31.13b
Nongda 6-2	6.77 ± 0.07bcde	80.30 ± 0.68b	2.82 ± 0.10bcde	17.68 ± 0.85d
Xushu 24	6.78 ± 0.01bcde	74.92 ± 0.75bcd	2.83 ± 0.12bcde	898.00 ± 84.85a
Luoxushu 9	5.75 ± 0.10g	64.44 ± 0.43e	2.40 ± 0.34f	4.94 ± 0.70d
Xushu 28	5.74 ± 0.08g	68.04 ± 0.45cde	2.39 ± 0.18f	3.64 ± 0.71d
Xushu18	6.81 ± 0.18bcde	90.33 ± 4.05a	2.84 ± 0.24bcde	246.00 ± 36.56c
Xushu 508	6.29 ± 0.87defg	78.21 ± 10.11b	2.62 ± 0.45def	30.60 ± 0.84d



Correlation between AC and characteristic values of ethanol fermentation in different sweetpotato varieties

Item	Ethanol yield	Fermentation efficiency	Fermentative strength	Fermented mash viscosity
Dry matter	0.622*	-0.318	0.675**	-0.078
Starch	0.625*	-0.302	0.677**	-0.090
Amylose	0.653**	-0.003	0.698**	0.132

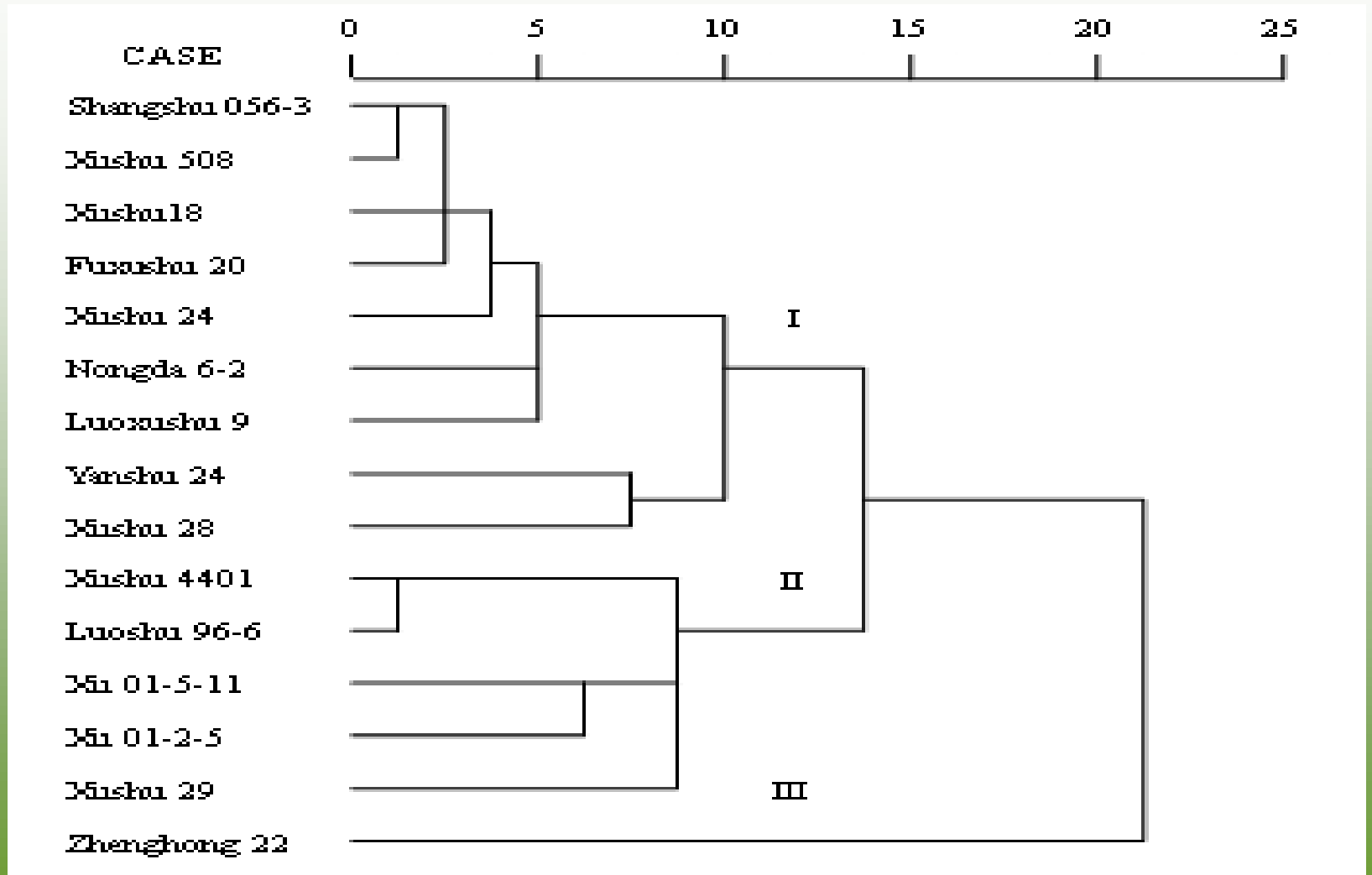


Correlation between characteristic values of RVA profile and ethanol fermentation in different sweetpotato varieties

Item	PKV	HPV	BDV	CPV	SBV	CSV	PT
Ethanol yield	-0.040	0.042	-0.103	0.009	0.105	-0.066	0.337
Fermentation efficiency	-0.113	0.048	-0.233	-0.026	0.218	-0.187	-0.391
Fermentative strength	-0.044	0.025	-0.096	-0.002	0.098	-0.061	0.356
Fermented mash viscosity	-0.379	-0.096	-0.563*	-0.141	0.639*	-0.231	0.208



Cluster analysis





Conclusion

- AC was positively correlated to ethanol yield, fermentative strength.
- Fermented mash viscosity was negatively correlated to BDV and positively to SBV.
- Consequently, AC and BDV could be used as index to evaluate the ethanol fermentation characteristics of sweetpotato.



Dietary fiber and ethanol fermentation



DF content in different sweetpotato varieties

Variety	TDF (%)	IDF (%)	SDF (%)	S/I
Fuxushu 20	13.14 ± 0.31fg	9.91 ± 0.23e	3.24 ± 0.08de	0.33 ± 0.03bc
Luoxushu 9	15.38 ± 0.09cde	11.98 ± 0.05bcd	3.39 ± 0.14de	0.28 ± 0.01c
Zhenghong22	14.34 ± 0.10efg	11.06 ± 0.44cde	3.28 ± 0.54de	0.30 ± 0.06c
Nongda6-2	14.89 ± 0.06defg	10.77 ± 0.01de	4.12 ± 0.05 abcde	0.38 ± 0.02 abc
Shangshu056-3	14.48 ± 0.02defg	10.96 ± 0.10cde	3.51 ± 0.11cde	0.32 ± 0.01bc
Luoshu96-6	12.09 ± 0.23g	9.30 ± 0.53e	2.79 ± 0.30e	0.30 ± 0.05c
Xushu29	19.02 ± 1.42ab	13.12 ± 0.12b	5.90 ± 1.54a	0.45 ± 0.12ab
Xushu4401	16.12 ± 0.16bcde	12.05 ± 0.26bcd	4.06 ± 0.10bcde	0.34 ± 0.02bc
Xushu18	16.96 ± 0.11bcde	12.77 ± 0.26bc	4.18 ± 0.15 abcde	0.33 ± 0.02bc
Xushu24	15.52 ± 2.13cd	10.53 ± 0.51de	4.98 ± 1.62abcd	0.47 ± 0.13a
Shangshu19	17.56 ± 3.32bcd	13.03 ± 2.35b	4.53 ± 0.97abcde	0.35 ± 0.01 abc
Sushu 3	21.29 ± 2.49a	15.73 ± 1.32a	5.56 ± 1.17ab	0.35 ± 0.05 abc



DF composition in different sweetpotato varieties

Variety	Pectin (%)	Hemicellulose (%)	Cellulose (%)	Lignin (%)
Fuxushu 20	32.52 ± 1.98ab	39.92 ± 4.17bcde	20.83 ± 4.65bcd	1.58 ± 0.35bc
Luoxushu 9	32.60 ± 0.39 ab	36.61 ± 2.40cdef	18.48 ± 1.68cd	2.55 ± 0.23a
Zhenghong22	31.44 ± 0.33 ab	45.80 ± 5.07ab	19.49 ± 4.63 bcd	2.05 ± 0.49abc
Nongda6-2	37.27 ± 0.23a	40.35 ± 2.06bcde	15.24 ± 1.56fg	1.53 ± 0.16c
Shangshu056-3	33.01 ± 1.38 ab	49.00 ± 5.01a	12.79 ± 2.58g	2.53 ± 0.51a
Luoshu96-6	33.56 ± 6.72 ab	42.62 ± 1.90abc	16.56 ± 6.00df	2.31 ± 0.84 abc
Xushu29	35.03 ± 0.77 ab	28.87 ± 0.50fg	25.26 ± 0.19abc	2.04 ± 0.02 abc
Xushu4401	33.05 ± 1.31 ab	34.31 ± 2.26defg	22.38 ± 2.44 abc	2.09 ± 0.23 abc
Xushu18	36.89 ± 2.01 ab	26.78 ± 4.17g	26.71 ± 4.55ab	2.50 ± 0.43a
Xushu24	37.41 ± 3.34a	33.04 ± 2.83efg	20.12 ± 0.35bcd	2.40 ± 0.04 abc
Shangshu19	32.91 ± 0.19 ab	37.09 ± 5.14cde	21.50 ± 3.82bcd	2.37 ± 0.42 abc
Sushu 3	29.93 ± 5.94b	35.66 ± 0.84 cde	24.45 ± 3.63abcd	1.70 ± 0.25 abc



The characteristics of ethanol fermentation in different sweetpotato varieties

Variety	Ethanol content(%)	Fermentation efficiency(%)	Fermented mash viscosity (Pa.s)
Fuxushu 20	11.46 ± 0.21ab	73.85 ± 2.94bcd	732.00 ± 42.42b
Luoxushu 9	8.63 ± 0.10g	64.44 ± 0.43e	4.94 ± 0.70d
Zhenghong22	9.92 ± 0.08cdefg	66.64 ± 0.28de	84.30 ± 5.66d
Nongda6-2	10.16 ± 0.07bcde	80.30 ± 0.68b	17.68 ± 0.85d
Shangshu056-3	10.71 ± 0.29abcd	77.98 ± 4.58b	4.33 ± 0.47d
Luoshu96-6	10.98 ± 0.35abc	78.84 ± 3.36b	2.84 ± 0.28d
Xushu29	9.30 ± 0.94efg	72.53 ± 0.61bcde	681.00 ± 31.13b
Xushu4401	11.85 ± 0.28a	68.71 ± 0.57cde	7.32 ± 0.28d
Xushu18	10.22 ± 0.18bcde	90.33 ± 4.05a	246.00 ± 36.56c
Xushu24	10.17 ± 0.01bcde	74.92 ± 0.75bcd	898.00 ± 84.85a
Shangshu19	8.75 ± 0.17fg	76.54 ± 4.80bc	10.10 ± 0.14d
Sushu 3	10.02 ± 0.54cdef	78.07 ± 5.84b	308.00 ± 11.31c



Correlation between DF composition and ethanol fermentation

Item	Ethanol content	Fermentation efficiency	Fermented mash viscosity
TDF	0.079	-0.303	0.292
IDF	0.130	-0.418	0.035
SDF	-0.031	-0.008	0.589*
S/I	-0.110	0.230	0.628*
Pectin	0.133	0.006	0.515**
Hemicellulose	0.270	-0.510	-0.244
Cellulose	-0.149	0.017	0.283
Lignin	-0.263	-0.106	-0.030



Conclusion

- SDF、S/I、pectin was positively correlated to fermented mash viscosity respectively, but was not significantly correlated to ethanol yield and fermentation efficiency.
- The other index of dietary fiber was not significantly correlated to ethanol fermentation characteristics.
- Consequently, SDF and pectin could be used as index to evaluate the ethanol fermentation mash viscosity .

Thanks for your attention

