

Adoption of Efficient Varieties Management for Improving Sugar Content Moisture Content, and Fermentation Parameters and Wine Quality of Different Sorghum (*Sorghum bicolor* L.)

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Abstract The water holding capacity, light transmittance, solubility and swelling power of waxy sorghum grain starch were higher than those of non-waxy sorghum. The six crystal structure types of sorghum starch were all type A. The absorption peak of waxy sorghum at a diffraction angle of 20.0° was weaker than that of non-waxy sorghum grain starch. The sorghum starch particle size ranged from 5 to 23 μm. 6 kinds of sorghum starch granules all showed typical "Maltese cross" by polarized light, and there were two clusters. The P1 value of LZ-19 (P1=66.5%) was the largest, which showed that the starch granules were larger and more complex; the P1 of waxy JN-3 (P1=33.8%) was the smallest, the starch granules were smaller, the granules were simpler, and the distribution was scattered, but there was no significant difference between waxy and non-waxy rice. The starting temperature, ending temperature and enthalpy value of waxy sorghum grain starch slurry were higher than those of non-waxy, and there were significant differences between waxy and non-waxy sorghum, indicating that the starch structure of waxy sorghum grain was more compact and orderly than that of non-waxy sorghum. It was easier to gelatinize, and the required heat was higher. The gelatinization temperature, gelatinization time and valley viscosity of waxy sorghum starch were higher than those of non-waxy sorghum, and there were significant differences in the gelatinization retrogradation characteristics of waxy and non-waxy sorghum starch.

Keywords: sorghum, yield; grain quality, physical and chemical properties, starch properties fermentation characteristics

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1. Introduction

Sorghum bicolor (L.) Moench is a C4 crop with high yield, drought resistance, Waterlogging resistance, salt and alkali resistance, barren resistance and high temperature resistance [1,2]. China important food crop in the arid regions of the north, which plays an important role in dry farming production [3]. Sorghum has a high economic value and is widely used in sugar, paper, board, beverage and alcohol refining. Sorghum can be used as an important source of animal feed and is also an important raw material for liquor brewing [4]. The main development direction of brewing sorghum research includes the breeding of new varieties, the analysis of physical and chemical properties of seeds, and the

technological parameters of liquor brewing. The separate study of various links, aiming at different varieties of sorghum grain quality, starch physicochemical characteristics, grain cooking quality. There are few comprehensive studies on the effect of environmental factors of pit on the quality of kaoliang liquor during fermentation. In recent years, with the continuous advancement of the pace of structural reform on the supply side of China's agriculture, the planting area of sorghum has shown an expanding trend due. The development is becoming more and more extensive, and the demand for sorghum is increasing [5,6]. Therefore, the system study is different high grain quality of sorghum varieties, physicochemical properties of starch, cooking quality of grain and environmental ecological factors of pit during fermentation is very important to conduct a series of related analyses on the influence of wine quality.

In order to screen out high-quality brewing sorghum raw materials. It is of great significance to provide theoretical support for the development of sorghum brewing industry and promote the special production of sorghum. There are a wide range of raw materials for brewing white spirits, but the styles of white spirits brewed from different raw materials are different quality may be different because of the variety of raw materials and the place of origin, the liquor brewed in the flavor, taste, style and wine yield. The faces are very different. As the main raw material of brewing liquor, sorghum not only has a high liquor yield, but also the liquor is mellow and rich. Compared with other brewing materials, sorghum has an important advantage. Solid state fermentation plays an important role in liquor brewing fermentation process was closely related to the complex material and energy metabolism of microorganisms in the pit of fermented grains [11,12]. Fermented grains refer to the fermentation of raw materials after cooking and pasting, and then adding koji to saccharify the hair. The leavened grain. It is the main body of liquor brewing and the substrate of microbial growth and metabolism during fermentation. Fermented grains hair. After fermentation, the microbial community in the pit began to change in an orderly manner, and good entry conditions could accelerate microgenesis metabolic activity of substances and the reproduction rate improved the fermentation quality of fermented grains [7,8]. With the fermentation of the process progressed, various substances in fermented grains would continuously emerge and disappear, and eventually different compositions formed among them. White spirits with different flavor characteristics [9,10]. The previous chapters are about the field performance of different sorghum varieties contents of grain, grain components, physicochemical properties of starch and cooking quality were preliminarily analyzed. This chapter will look at different sorghum products. The dynamic change of the indexes of fermented grains in the process of fermentation was monitored, and the brewing mechanism of liquor was further analyzed high liquor brewing technology level and liquor quality provide some theoretical basis.

2. Materials and Methods

2.1. Test Materials

Sample source: The sorghum varieties tested are the Shanxi Key Laboratory of Sorghum Genetic and Germplasm Innovation and only the height is changed on the basis of the current "round cellar" process of wine. The fermentation time of the varieties was 26 d. Samples were taken every 3 d from the beginning of the cellar, and the samples were continuously sampled until. Production is over. Take the fermented grains from the middle of the pit and the four corners of the pit and pour them into the top, middle and middle grains. After mixing them evenly, take samples and put them into sterile bags and seal them. Transported to the laboratory in an ice box and kept at -80 °C for testing.

2.1.1. Test Methods

The brewing test was carried out in Shanxi Key

Laboratory of Sorghum Genetic and Germplasm Innovation. The production process of Feng-flavor liquor was shown in based on the current "round cellar" process, only sorghum varieties were changed to carry out the test, respectively in 6 cellars the same time. Grain feeding: each round of each variety of grain feeding 900 kg, Daqu: 20±1% of the grain feeding, about 210 kg, auxiliary Material: 225 kg, inlet temperature (average temperature in the pit): 18-22°C, inlet water (average moisture in the pit). 57-61%, crushing degree of sorghum: 4-6 pieces, Daqu crushing degree: grain, steamed sorghum for more than half an hour, auxiliary materials steam for more than 90 minutes. Under the current "round cellar" process, the continuous fermentation days of Xifeng wine are 26 days, and the tracking is different liang varieties of 6 pit.

2.1.2. Fermented Grains

Infrared drying method was used to determine the moisture of fermented grains [13]. The wine was sampled by a quarter method 10 g of fermented grains were put into a surface dish, then flattened, and baked in an infrared oven for about 20 minutes at a temperature controlled at a minimum 100 ~ 105 °C, cool to room temperature, weigh. The calculation formula is as follows:

$$\text{(Sorghum bicolor L.) Moench) (\%)} = \frac{W - W_0}{W} \times 100\%$$

Where: W is the weight of the original sample; W₀ is the sample mass after drying.

2.1.3. Fermented Grains

The gravity method was used to determine the content of fermented grains. The use of alcohol meter to measure alcohol content, determination of alcohol in fermented grains, first alcohol in fermented grains was steamed by distillation, and the alcohol content was measured by alcohol meter. Distilled alcohol from fermented grains. Methods samples of fermented grains with a mass of 100 g were weighed and placed in a 500 mL distilling flask, and then 200 mL of water was added distilled liquid is distilled in a distillation flask, and 100 mL of effluent is collected in a 100 mL cylinder. Steam distilled liquor is evenly mixed and gently put into a clean alcohol meter. After stabilizing, the alcohol is read at the liquid level. Degree; while measuring the temperature of the liquor. According to "Alcohol and temperature correction table", and set the alcohol correction value 20 degrees Celsius.

2.1.4. Starch and Reducing Sugar in Fermented Grains

The contents of starch and reducing sugar in fermented grains were determined by Fehling reagent method.

2.1.5. Wine Yield

The alcohol yield was determined with reference to previous methods Fermented grains in six pit ponds distillation, 65%vol wine was extracted. The comprehensive alcohol content of raw wine was calculated according to 65°. The ratio of the amount of alcohol produced is calculated. The calculation formula is as follows:

$$\text{Liquor yield (\%)} = \text{liquor yield/grain yield} \times 100\%$$

2.1.6. Determination of Main Aroma Substances in Raw Wine

Liquid-liquid microextraction with gas chromatography-mass spectrometry is used chromatography - mass spectrometry, LLME-GC-MS) was used to extract aroma compounds from different sorghum wine samples quantitative analysis. Take 18 mL alcohol 10%vol diluted wine sample, add 6 g NaCl to saturation, 6 μ L internal standard butyl caproate (5.85 mg/L), Add 1 mL of resteamed ether to extract it, fully oscillate for about 3 min, and then take 1 μ L after it is left to stand and stratified upper layer extractant was analyzed by GC-MS. GC conditions. inlet temperature 250°C, carrier gas high purity helium, flow rate 2 mL/min, no shunt injection; Heating procedure: the initial temperature is 50°C, the temperature remains unchanged for 2 min, and the temperature rises to 230°C at 6°C/min for 15 min. MS condition: electron ionization source (EI). The electron energy is 70 eV transmission line temperature is 230 °C; Ion source temperature is 250 °C; Scanning range 30-350 u. Methods for the identification of volatile substances in raw wine: First The spectra of volatile compounds were compared with those of NIST08 standard database, and the matching degree was great In 800 as preliminary qualitative results. The calibration curve is further analyzed according to the peak area of the compound concentration of the compound was calculated relative to the ratio of the peak area of the internal standard. For specific operation steps.

3. Results

3.1. Temperature Changes in Fermented Grains of Different Sorghum Varieties During the Fermentation Process

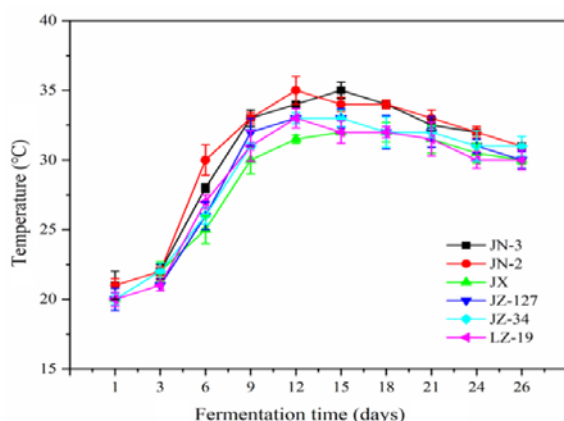


Figure 1. Temperature changes of different sorghum varieties during fermentation

During the fermentation process, the temperature of fermented grains mainly depended on the growth of microorganisms and the speed of metabolic activities (Figure 1). The overall temperature variation of fermented grains at 26 d was as follows. The temperature changes slowly in the early stage, rises rapidly in the middle stage, and decreases gradually in the late stage. At the beginning of fermentation, 6 cellars are used for wine. The temperature

of fermented grains gradually began to rise and reached the maximum value at 13-15 d. JN-2, JZ-127, LZ-19, and JZ-34. The temperature of fermented grains reached the highest after 12 d, while the temperature of JN-3 and JX reached the highest after 15 d. It shows that in the middle stage of fermentation some acid-producing microorganisms dominate, and fermentation will slowly enter the acid-producing stage, wine. The acidity of fermented grains would slowly increase, which also led to a decrease in the activity of acid-resistant microorganism. Metaphase knot. After bunching, the temperature in the pit is slowly lowered and enters the stage of aroma production until the end of fermentation.

3.2. Changes of Moisture in Fermented Grains of Different Sorghum Varieties During Fermentation

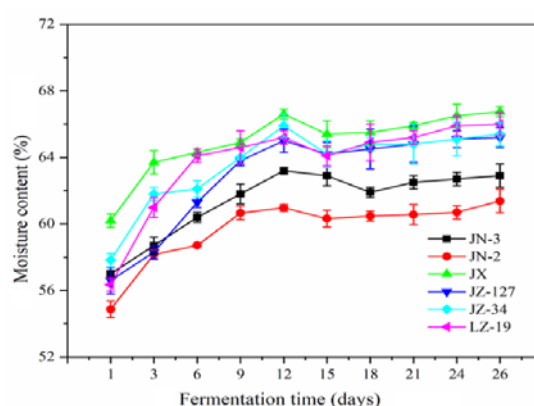


Figure 2. Changes of moisture content of different sorghum varieties during fermentation

Water content is one of the important control indexes of liquor solid fermentation. The moisture content in fermented grains of different sorghum varieties changed (Figure 2). During the fermentation process, the variation trend of moisture content in fermented grains in the six cellars was basically the same. Water content increased rapidly first, then slowed down and decreased, and then slowly rose and became smooth. But between glutinous rice and glutinous sorghum. The water content of non-glutinous sorghum was higher than that of glutinous sorghum. Moisture content in fermented grains of japonica JX was always higher than that of japonica JX He has 5 varieties of sorghum, and waxy JN-2 has the least water content. How much water content in fermented grains was related to microbial life long related, under the action of microorganisms, raw materials are constantly consumed and fermented, a large number of microorganisms grow and reproduce rapidly. A large amount of water was produced by accelerated absorption metabolism, and the water content in fermented grains gradually increased and reached saturation.

3.3. Acidity Changes in Fermented Grains of Different Sorghum Varieties During the Fermentation Process

The acidity changes of fermented grains of different sorghum varieties at different fermentation times were

Figure 3. During the first 3 days of fermentation, the acidity of fermented grains decreased, and the acidity changed little from 3 d to 9 d. Due to the early stages of fermentation, fermented grains temperature is relatively low, the mold and yeast in the pit occupy the main advantage, and the number of acid-producing bacteria is small, resulting in acid. After 9 days, the acidity of fermented grains gradually increased, on the one hand, because of the temperature. As the degree increases, acid-producing bacteria multiply and metabolize rapidly. In addition, a large amount of reducing sugar is rapidly utilized by acid-producing bacteria. In the late fermentation period, due to the death of a large number of yeast, the amount of ethanol produced is reduced, and the fermentation mainly enters the acid production stage. Various organic acids will appear in the stage, accompanied by esterification reaction. However, compared with the acidity of several kinds of sorghum grains, the acidity of fermented grains remained stable after 15 days of JX. This is conducive to the progress of fermentation, and the wine yield will be improved. Because the acidity in fermented grains was too high, the fermentation rate decreased also directly affects the rate of wine.

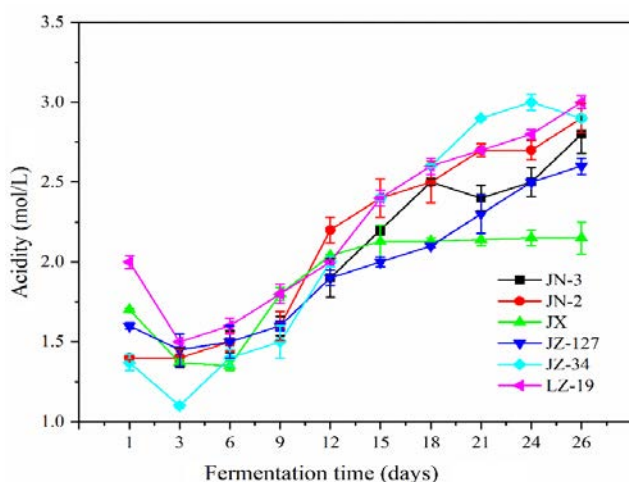


Figure 3. Changes in acidity of different sorghum varieties during fermentation

3.4. Changes of Starch Content in Fermented Grains of Different Sorghum Varieties During Fermentation

The trend of starch content change over time in the fermentation process of different sorghum varieties. As can be seen from **Figure 4**. The starch content in fermented grains of JX was the highest and the lowest was JZ-127. With the extension of fermentation time, starch content, however, the starch content in fermented grains decreased rapidly before the 6th day, which was mainly due to the early stage of fermentation. The oxygen and nutrients in fermented grains were abundant, which was conducive to the rapid reproduction and metabolic activities of other microorganisms such as yeast. And then they produce a lot of saccharifying enzymes. Under the action of a large number of saccharification enzymes, starch is rapidly transformed into reducing sugar. After the

6th day, the starch content in fermented grains decreased slowly. At the 26th day, the starch in fermented grains was basically absent. Then the starch content in fermented grains of JX was slightly higher than that of other five sorghum varieties, and the lowest was JZ-127.

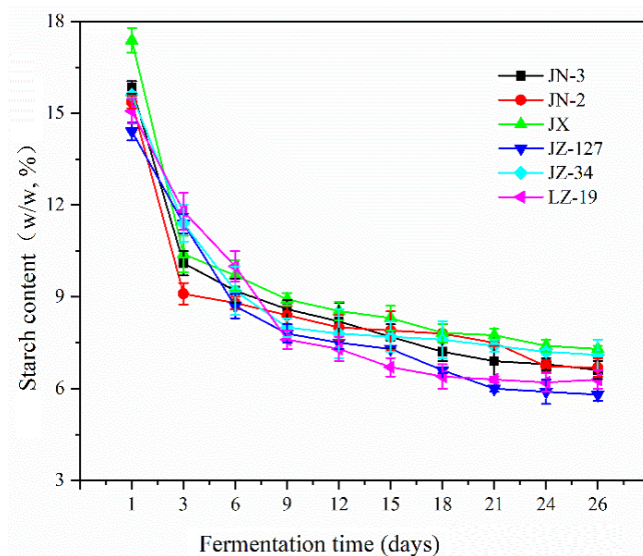


Figure 4. Changes of starch content in different sorghum varieties during fermentation

3.5. Changes of Reducing Sugar Content in Fermented Grains of Different Sorghum Varieties During Fermentation

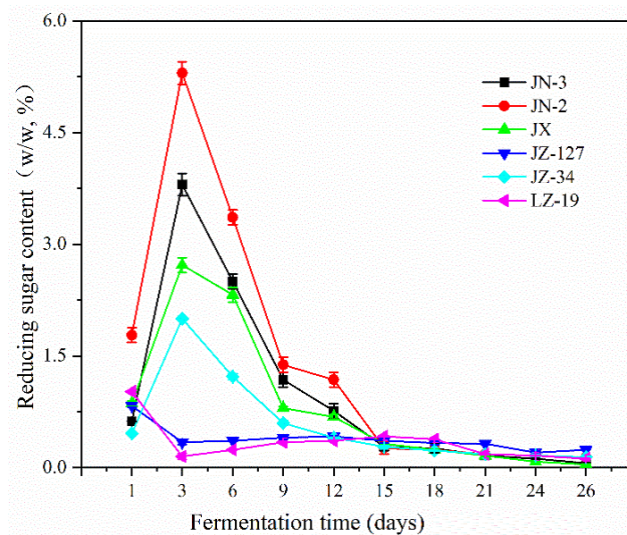


Figure 5. Changes of reducing sugar content in different sorghum varieties during fermentation

The change of reducing sugar content in fermented grains of different sorghum varieties during the fermentation process See **Figure 5**. It was found that the reducing sugar content in fermented grains of JN-2, JN-3, JX and JZ-34 increased first and then Decrease JZ-127 and LZ-19 decreased first, then increased slowly, and then decreased. At 3rd day JN-2, JN-3. The reducing sugar content in fermented grains of JX and JZ-34 reached the peak, while that of JZ-127 and LZ-19 decreased. Appear contrast may be caused by factors such as the content of

raw material itself and the change of microbial population in the pit.

3.6. Comparative Analysis of Aroma Substances in Different Sorghum Wines

Table 1. Main flavor content of different sorghum liquor varieties

Index	mg/100 mL					LZ-19
	JN-3	JN-2	JX	JZ-127	JZ-34	
Ethyl acetate	109.23	85.86	229.29	180.30	151.14	156.54
Ethyl hexanoate	42.18	43.74	72.47	81.21	69.94	84.66
Ethyl lactate	218.13	193.89	146.0	150.74	148.04	227.98
Ethyl butyrate	3.27	3.79	5.67	7.44	7.23	8.49
N-propanol	35.77	26.06	35.75	38.41	54.53	41.89
N-butanol	27.62	22.95	18.73	34.56	24.78	37.25
Iso-butanol	10.00	9.31	12.79	14.00	12.51	15.23
2-butanol	2.67	2.40	4.90	3.09	4.18	3.72
Iso-pentanol	38.08	33.42	42.19	43.56	41.97	48.37

The determination results of main aroma substances in different sorghum varieties of raw wine. As shown in Table 1, japonica. The contents of four major esters in sexual sorghum wine were higher than those of waxy except ethyl lactate. Among them, waxy content of ethyl acetate in JN-2 raw wine is the least, which is 85.86 mg/100 mL, while the content of ethyl acetate in japonica JX raw wine is the least. The content of ester was the highest (229.29 mg/100 mL), and the content of ethyl lactate was the least (146.00 mg/100 mL). The highest contents of ethyl caproate, ethyl lactate and ethyl butyrate in japonica LZ-19 raw wine were 84.66 mg/100, respectively. The mL, 227.98 mg/100 mL, 8.49 mg/100 mL. In the composition of flavor substances of japonica JX raw wine, B ethyl acid content accounts for half of the total ester content, and secondly, the ethyl lactate content in JX raw wine accounts for one of the ethyl caproate Half, an appropriate amount of ethyl lactate is beneficial to the style of white wine, while excessive ethyl lactate will cause the astringency of white wine and decrease Its quality (Fu Guocheng 2016; Liu Qiang 2020). The contents of n-propanol, n-butanol, secondary butanol, isobutanol and isoamyl alcohol in the alcohols in japonica raw wine are all the same content of n-propyl alcohol and n-butanol in japonica JX original wine is slightly lower than that of waxy. Waxy JN-2. The contents of n-propanol, isobutanol, secondary butanol and isoamyl alcohol in raw wine are the lowest, and their contents are 26.06, 9.31, 9.31, respectively. 2.40, 33.42 mg/100 mL; The content of secondary butanol in JX original wine is the highest, which is 4.90 mg/100 mL, and the content of n-butanol lowest value was 18.73 mg/100 mL. The contents of n-butanol, isobutanol and isoamyl alcohol in LZ-19 were the highest, respectively 37.25, 15.23 and 48.37 mg/100 mL. Alcohol compounds play an important role in the content of liquor components, not. Alcohol compounds with the same composition will change their aroma composition and thus change the liquor style, especially the high content of higher alcohols. It will change the taste

and fragrance of liquor, leading to the decline of liquor quality. Contents of main aroma substances in different sorghum varieties of raw wine.

4. Discussion

Studied Luzhou-flavor liquor and found that the fermentation temperature of fermented grains showed "early stage slow and middle stage. Very, late slow down "change trend [14,15]. Described the physicochemical process of fermented grains of Feng-flavor liquor. The results showed that the temperature of fermented grains rose slowly in the early stage, and then rose rapidly in the middle stage Rise, later becomes flat and slowly decline until the end of fermentation; The acidity of fermented grains increased slowly in the early stage and quickly in the middle and late stages Rapid ascent; After fermentation, the starch content decreased significantly in the early stage, and the rate decreased significantly in the middle and late stages, and gradually fluctuated and balanced. This was basically consistent with the change rule of fermented grains indexes in this study, but in the fermented grains of 6 different sorghum varieties during the fermentation process. The reducing sugar content in JZ-127, LZ-19 and other four kinds of sorghum grains showed a trend of change over time content of the other four species increased first and then decreased, while JZ-127 and LZ-19 decreased first. Then it slowly increases and then decreases. This contrast may be due to the content of the raw material itself and the microbial population in the pit Caused by changes and other factors [16]. studied the physicochemical indexes of the fermented grains in the fermentation process of Luzhou-flavor liquor. The results showed that the contents of moisture and alcohol in fermented grains changed little and tended to change after 10 days After 20 days, the total acid content in fermented grains tended to be balanced, the pH value showed a decreasing trend, and the reducing sugar and sugar in fermented grains Starch rapidly decreased in the first 20 days, and the total ester in the first 10 days of fermented grains rapidly increased and then decreased during the fermentation process There was obvious regularity in the change of the indexes of grains and physics [17]. Found that the main substances that produce alcohol. It is believed that the more starch content of sorghum, the higher the yield of wine. In this study, the total starch content of JX was the highest. The results showed that the yield of wine was also the highest among the 6 kinds of sorghum, which was exactly consistent with the research results. The flavor characteristics of Feng-flavor liquor are mainly that the mellow flavor is very elegant, the taste is sweet and quite cool, and the taste is more harmonious and drinky Long aftertaste. The main aroma substance is ethyl acetate, plus a certain amount of ethyl caproate as an auxiliary. According to the national standard, the content of ethyl acetate in liquor of excellent quality must be higher than 0.60g/L, ethyl caproate content should be between 0.15 g/L~1.5 g/L (Fu Guocheng 2016). Ethyl acetate in Fengxiang liquor. The content of ester is generally between 80 and 180 mg/100 mL, which is very close to the Luzhou-flavor liquor ethyl acid content is between 10 and 50 mg/100 mL,

which is lower than Luzhou-flavor liquor, but it is white with clear flavor. The wine contrast is relatively high. Xifeng wine is one of the main quantity ratio relations between Qingflavor wine and Luzhou-flavor liquor. Phoenix fragrance type ratio and content of ethyl acetate and ethyl caproate in liquor must be within a certain range, and the proportional relationship and absolute. The content is generally between 1:0.12 and 0.37, and the greater the ratio in this range, the better the wine quality and the more mellow the taste. The aroma is relatively strong. The comparison of 6 varieties in this study showed that the ratio of ethyl acetate to ethyl caproate was the highest in this range good one is JX white wine (1:0.32). The content of ethyl lactate in Fengxiang liquor is between 30~80 mg/100 mL in this range, the lower its content, the better the wine quality, but in the production process, Fengxiang liquor ethyl lactate content. They tend to exceed that. This is consistent with the results obtained in this study, the content of ethyl lactate in 6 kinds of kaoliang liquor. The content and type of higher alcohols have a great impact on the aroma and taste of the wine, and a certain concentration is high. Grade alcohols give the wine a special aroma. When the concentration of higher alcohols in wine is low, the wine taste is weak and the taste is poor. When the concentration is high, there will be mixed taste, and it is easy to "head" after drinking. A certain proportion of higher alcohols is also very important. It is found that the higher alcohols in wine are mainly composed of isobutanol and isoamyl alcohol, and when the isobutanol content is less than the isoamyl alcohol content of wine. The quality is good. The ratio between the two is appropriate at 1:2 to 5 [18]. According to the results of this study. The proportion of wine has exceeded this proportion range, but the range of JX is closer to this range, and its wine quality is better.

5. Conclusion

The acidity of fermented grains is 15 trend was basically the same before the day, but after 15 days, the acidity of JX fermented grains remained stable, and the other fermented grains continued to rise. Cellaring. After fermentation, the starch content decreased gradually with the extension of fermentation time, and there was no obvious difference between different varieties. The reducing sugar content of JZ-127 and LZ-19 in fermented grains 3 days before fermentation showed opposite trends. Along with hair. With the increase of fermentation days, the alcohol level also increases with the increase, and the alcohol level reaches the highest at 21 d. Comparing the yield results of different sorghum varieties, the yield of japonica JX reached the highest 41.61%, but the yield of japonica JX reached 41.61%. There was no significant difference between sexual JX and waxy JN-3, and the lowest alcohol yield was JZ-127 (35.94%). The content of main aroma substances in different sorghum wines was compared. The results showed that in sorghum wine contents of ethyl acetate, ethyl caproate and ethyl butyrate were higher than those of waxy. Which waxy JN-2 original wine. The content of ethyl acetate in japonica JX raw wine was the lowest, and the content of ethyl acetate in japonica JX raw wine was the highest, and the content

of ethyl acetate accounted for the total. Half of the ester content, and the least ethyl lactate content. The ratio of ethyl acetate to ethyl caproate was 1:0.32. The contents of isobutanol, secondary butanol and isoamyl alcohol in non-glutinous sorghum wine were higher than those in glutinous sorghum. Among them. The contents of n-propanol, isobutanol, secondary butanol and isoamyl alcohol in waxy JN-2 raw wine were the lowest. Japonica JX raw wine Nakaka Butanol content was the highest and n-butanol content was the lowest.

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References

- [1] Yan S B, Wang S C, Wei G G, Zhang K G. 2015. Investigation of the main parameters during the fermentation of Chinese Luzhou-flavour liquor. *Journal of the Institute of Brewing*, 121(1): 145-154.
- [2] Mekbib F. 2008. Genetic erosion of sorghum (*Sorghum bicolor* (L.) Moench) in the centre of diversity, Ethiopia. *Genetic Resources & Crop Evolution*, 55(3): 351-364.
- [3] Aina A J, Falade K O, Akingbala J O, Titus P. 2012. Physicochemical properties of Caribbean sweet potato (*Ipomoea batatas* (L) Lam) starches, *Food Bioprocess Technol.* 5 (2) 576-583.
- [4] Eugenia S M, Edel L A, Teresa P G. 2013. Study of the physicochemical and functional characterization of quinoa and kaniwa starches. *Starch/Stärke*, 65(11-12): 976-983.
- [5] Chen M B, Yang D D, Qian Z W, D Zhen, Fang S L. 2010. Analysis of microorganisms and physicochemical properties in zaopei during the fermentation of chinese zhijiang-flavor liquor. *African Journal of Biotechnology*, 9(25), 3874-3882 Mekbib F. 2008. Genetic erosion of sorghum (*Sorghum bicolor* (L.) Moench) in the centre of diversity, Ethiopia. *Genetic Resources & Crop Evolution*, 55(3): 351-364.
- [6] Uarrota V G, Amante E R, Demiate I M, Vieirad F, Delgadillo I, Maraschina M. 2013. Physicochemical, thermal, and pasting properties of flours and starches of eight Brazilian maize landraces (*Zea mays* L.). *Food Hydrocolloids*, 30(2): 614-624.
- [7] Ambigaipalan P, Hoover R, Donner E, Liu Q, Jaiswal S, Chibbar R, K K M, Nantanga, K. 2011. Structure of faba bean, black bean and pinto bean starches at different levels of granule organization and their physicochemical properties. *Food Research International*, 44(9): 2962-2974.
- [8] Beta T, Corket H. 2001. Genetic and environmental variation in sorghum starch properties. *Journal of Science*, 34: 261-268.
- [9] Chen Z, Schols H A, Voragen A G J. 2003. Physicochemical properties of starches obtained from three varieties Chinese sweet potatoes. *Journal of Food Science*, 68(2): 431-437.
- [10] Cheng F M, Zhong L J, Zhao N C. 2005. Temperature induced changes in the starch components and biosynthetic enzymes of two rice varieties. *Plant Growth Regulation*, 46(5): 87-95
- [11] Hu XL, Du H, Ren C, Xu Y. 2016. Illuminating anaerobic microbial community and co-occurrence patterns across a quality gradient in Chinese liquor fermentation pit muds. *Applied and Environmental Microbiology*, 82(8): 2506-2515.
- [12] Zhao. 2015. Characterization of volatile aroma compounds in different brewing barley cultivars. *Journal of the Science of Food and Agriculture*, 95(5).
- [13] Niba L L. 2002. Resistant Starch: Apotential Functional Food Ingredient. *Nutrition & Food Science*, 32:62-67.
- [14] Raina C S, Singh S, Bawa A S, Saxena D C. 2006. Some characteristics of acetylated, cross-linked and dual modified Indian rice starches. *European Food Research and Technology*, 223: 561-570.

- [15] Suhendro E L, Mcdonough C M, Rooney L W, Waniska R D, Yetneberk S. 1998. Effects of processing conditions and sorghum cultivar on alkaline-processed snacks. *Cereal Chemistry*, 75(2), 187-193.
- [16] Torruco-Uco J, Betancur-Ancona D. 2007. Physicochemical and functional properties of makal. (*Xanthosoma yucatanensis*) starch. *Food Chemistry*, 101(4): 1319-1326.
- [17] White P J, Abbas I, Pollak L, Johnson L. 1990. Intra- and interpopulation variability of thermal properties of maize starch. *Cereal Chemistry*, 67: 70-73.
- [18] Zhang Yanyan, Zhu Xiaoyu, Li Xiangzhen, Tao Yong, Jia Jia, He Xiaohong. 2017. The process-related dynamics of microbial community during a simulated fermentation of Chinese strong-flavored liquor. *BMC microbiology*, 17(1).



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