JARQ 33, 69–75 (1999)

Production of Shochu Spirit from Crushed Rice by Non-Cooking Fermentation

Kenryo NISHIMURA*[1], Kenji KIDA*[2], Masaru NAKAGAWA*[1], Kimi TSUCHIYA*[1] and Yorikazu SONODA*[3]

*[1] Department of Applied Microbiology, Kumamoto Industrial Research Institute (3-11-38 Higashi-machi, Kumamoto, 862-0901 Japan)
*[2] Department of Applied Chemistry, Faculty of Engineering, Kumamoto University (2-39-1 Kurokami, Kumamoto, 860-0862 Japan)
*[3] Prefectural University of Kumamoto (3-1-100 Tsukiide, Kumamoto, 862-0920 Japan)

Abstract

A non-cooking fermentation system for shochu spirit production was evaluated using both small-scale and bench pilot-scale equipment. This system employed a commercially available fungal enzyme preparation as saccharifying agent together with citric acid. The fermentation products from bench-scale equipment were distilled under vacuum or atmospheric conditions and the distillates were evaluated by a taste panel. Distillates produced under atmospheric conditions by the non-cooking fermentation method compared favorably with those produced by the cooking fermentation method. This method of production could result in significant savings of labor and energy if operated on a production scale. A case study and an analysis of economic aspects were carried out in a medium-scale shochu spirit factory.

Discipline: Food
Additional key words: atmospheric and vacuum distillation, flavor and aroma components, economic aspects

Introduction

Economic pressures on many small to medium-sized shochu spirit distilleries require a reduction in the labor force. In spirit production in Japan, pretreatment of cereal raw materials by cooking and preparation of "koji" for saccharification are the most labor-intensive operations and account for 30% of the total work load.

Recently, because of the trend toward milder tasting spirits, distillers have concentrated their attention to the development products that will meet this trend, by use of vacuum distillation or ion exchange treatments. Investment in the equipment needed for these processes will lead to unavoidable increases in costs. Investigations have therefore been carried out on systems based on a non-cooking method and employing exogenous saccharifying enzymes. These are designed to produce a mild spirit while saving labor and energy. A "non-cooking fermentation" method[2] was developed by the addition of citric acid, and the fermentation progression depended on the commercial enzyme preparations used. It was also evident that the aroma and flavor compounds were derived from the cereal mash, especially higher fatty acid esters.

This paper describes investigations on the practical applications of these results. A bench-scale pilot plant was then used to follow the changes in the concentrations of the flavor and aroma compounds with time. Finally, sensory tests were carried out on the products obtained by atmospheric and vacuum distillation. In the case study, attempts were made to determine whether this non-cooking fermentation system could be introduced into a shochu spirit factory. From the economic point of view, this system may enable to reduce of cost for manufacturing by about 10%.

Materials and methods

1) *Bench-scale fermentation test*

The production of spirit by non-cooking and cooking fermentation methods was investigated using the bench-scale plant shown in Fig. 1. The stainless steel

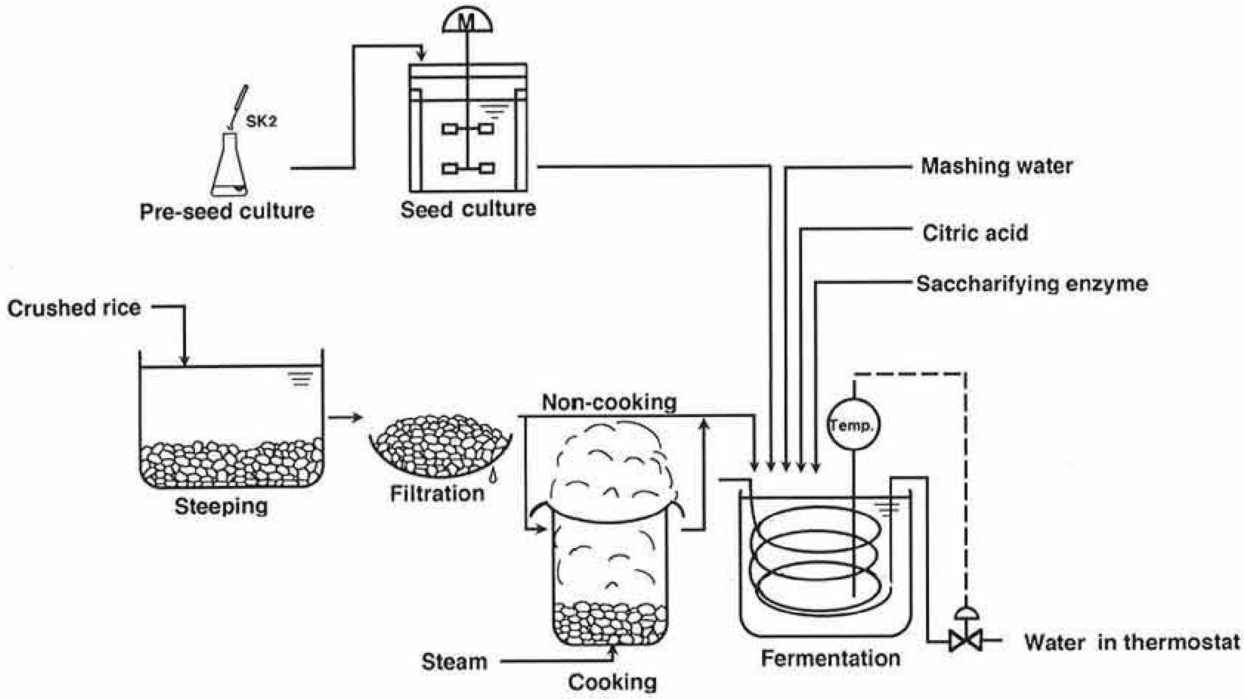

Fig. 1. Scheme of non-cooking and cooking fermentation systems in the bench-scale plant

fermentation tank had a 130 L capacity and the temperature was controlled at 25°C. Crushed rice grains (50 kg) were steeped in tap water overnight and filtered for 1 h; 75 L of mashing water (mashing water rate 150%) containing 0.2% (w/v) of citric acid and 100.6 g of enzyme preparation E (0.1 g protein/100 g crushed rice) were added to the fermentation tank, followed by 4.5 L of suspended yeast. The temperature was controlled at 25°C. A cooking fermentation test was conducted as a control using cooked rice that had been boiled for 30 min. The mashes were stirred 2–3 times a day with a paddle. The yeast inoculum used in this fermentation test was prepared as follows: 100 mL of seed prepared as in the small-scale fermentation test was added to a 30 L fermenter containing 18 L of sterilized medium and cultured at 25°C for 20 h at an aeration rate of 0.1 v/v min.

2) Distillation method

After the completion of the fermentation, the 120 L mash was divided into 2 equal parts, and one-half was subjected to distillation in a 100 L vessel that could be adapted to either atmospheric or vacuum distillation. Distillation at atmospheric pressure was carried out at 99°C for 60–70 min, whereas vacuum distillation was carried out for 75–90 min until the temperature had risen from the starting temperature of 35°C to a final temperature of 43°C. The distillates were stored at 2°C for 10 days and then filtered through No. 2 filter paper. Tap water was added to the filtrates to obtain products with an ethanol concentration adjusted to 25% (v/v).

3) Analytical methods

The acidity of the mash was analyzed according to the analytical method stipulated by the National Tax Administration Agency[1]. The concentration of ethanol in the mash was estimated using a gas chromatograph (GC-7A Shimadzu, Kyoto). The column (3 × 1 mm) was packed with Porapak Q and equipped with a flame ionization detector. Isopropanol was used as an internal standard. Flavor components with a low boiling point other than isoamyl acetate and ethyl capronate, were analyzed by the direct injection method according to Nishiya's method[5]. The contents of isoamyl acetate and ethyl caproate were determined by gas chromatography based on the head-space method. One mL of the internal standard solution (10^3 mg/L *n*-isoamyl alcohol solution) was added to a 30 mL vial containing 5 g of mash or 5 g of the product. The vial was hermetically sealed with a septum and an aluminum cap, and heated at 50°C for 20 min, then 1 mL of the head-space gas from the vial was subjected to gas chromatography (14A, HHS-2A, Shimadzu, Kyoto).

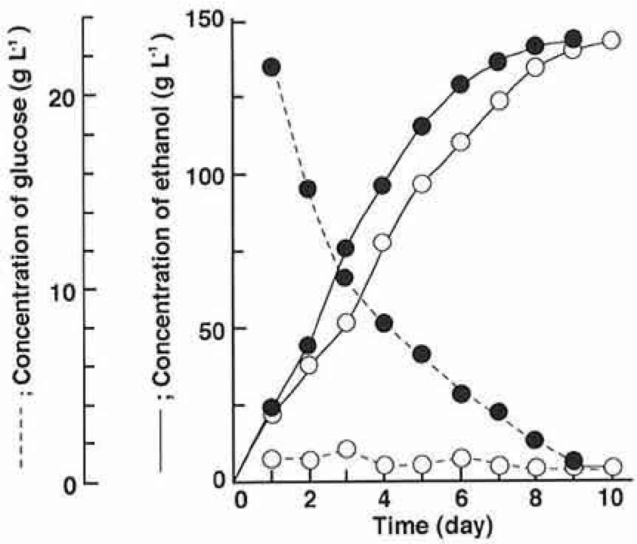

Fig. 2. Time course of ethanol and glucose concentrations in mash in 2 types of fermentation using the bench-scale plant
○; Non-cooking, ●; Cooking.

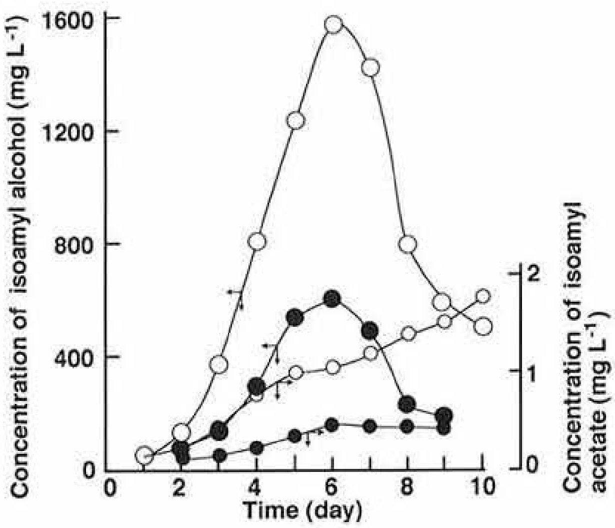

Fig. 3. Time course of isoamyl alcohol and isoamyl acetate concentrations in mash during batch fermentation using the bench-scale plant
○; Non-cooking, ●; Cooking.
Large circle; Isoamyl alcohol, Small circle; Isoamyl acetate.

The temperature gradient employed was 5°C/min from 50°C to 120°C. The detailed analytical conditions were described in the previous report[2]. The flavor components with a high boiling point in the mash after distillation were extracted by the addition of 60 mL of ether to 5 mL of the distillate and assayed by gas chromatography. The products obtained by distillation were also analyzed in the same way. The concentration of glucose in the mash was analyzed according to the gluco-stat method using an F-kit (Yamanouchi Seiyaku K. K., Tokyo), and organic acid components were analyzed by the post-label method[3] using a high-speed liquid chromatograph.

Results and discussion

1) Production of spirit based on the bench-scale fermentation test

The conditions of the bench-scale fermentation test were established based on the results from the small-scale fermentation test, i.e. 3% seed inoculum and a fermentation temperature of 25°C were used. The time course of fermentation is shown in Fig. 2. Fermentation was completed on the 10th day in the non-cooking fermentation method, which is only slightly different from the 9 days required for the completion of the fermentation process in the case of the cooking fermentation method. The difference was due to the initial concentration of glucose in the mashes; this concentration for the cooking fermentation method was 22.3 g/L, whereas 1.3 g/L for the non-cooking fermentation method. The rate of saccharification therefore limited the fermentation rate in the non-cooking fermentation method. A clear advantage of this system, however, was the lower level of bacterial contamination.

2) Flavor and aroma components during the fermentation

The changes in the concentrations of the aroma and flavor components during the fermentation are shown in Figs. 3–5. Isoamyl alcohol concentration increased in both the cooking and non-cooking fermentation systems at the early stage of fermentation, but decreased in the latter period. The concentration of isoamyl acetate derived from isoamyl alcohol increased during the latter period of fermentation in the non-cooking fermentation system (Fig. 3). The amounts of β-phenethyl alcohol and β-phenethyl acetate formed in both the cooking and non-cooking fermentation systems are shown in Fig. 4. Both components were present at different concentrations in the cooking and non-cooking fermentation systems but the concentrations increased with the progression of the fermentation and then reached a constant level (Fig. 4).

Since the changes in the concentrations of ethyl myristate, ethyl oleate and ethyl linoleate showed

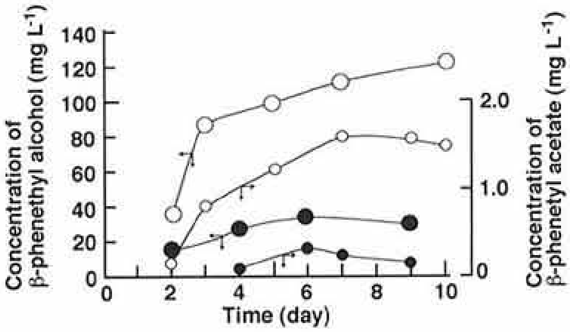

Fig. 4. Time course of β-phenethyl alcohol and β-phenethyl acetate concentrations in mash during batch fermentation using the bench-scale plant
○; Non-cooking, ●; Cooking.
Large circle; β-phenethyl alcohol,
Small circle; β-phenethyl acetate.

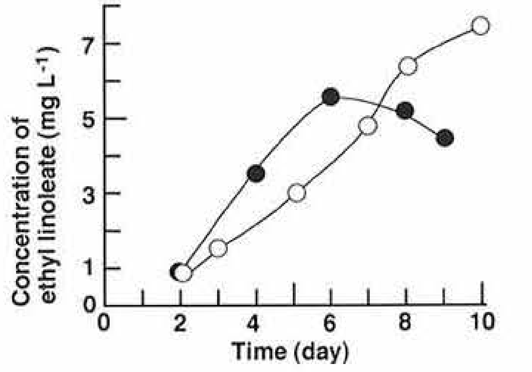

Fig. 5. Time course of ethyl linoleate concentrations in mash during batch fermentation using the bench-scale plant
○; Non-cooking, ●; Cooking.

almost the same behavior, the increase of the concentration of ethyl linoleate is shown in Fig. 5. The amount of ethyl linoleate reached the highest level during the middle stages of fermentation in the cooking fermentation system and decreased in the latter period of fermentation, whereas the ethyl linoleate concentration increased during the latter period of the fermentation in the non-cooking fermentation system. The analytical values of the flavor components with a high boiling point therefore confirmed the data from the small-scale fermentation test, the values being 11/32 as high as the values obtained in the conventional method (small-scale fermentation test[2]). A system using the enzyme preparation E was therefore considered to be suitable for the production of mild spirit.

The above results suggest that the concentrations of all the aroma and flavor components formed with low, medium and high boiling points were high in the non-cooking fermentation system. These results are similar to those obtained in the small-scale fermentation test as described in the previous report[2], because the free fatty acids contained in the raw materials were volatilized by cooking[7].

3) *Effect of distillation method on aroma and flavor product components*

The mashes from the non-cooking and cooking fermentation systems were subjected to atmospheric and vacuum distillations using the same still. The sensory test for the products was carried out according to a 5-point method by 14 panelists.

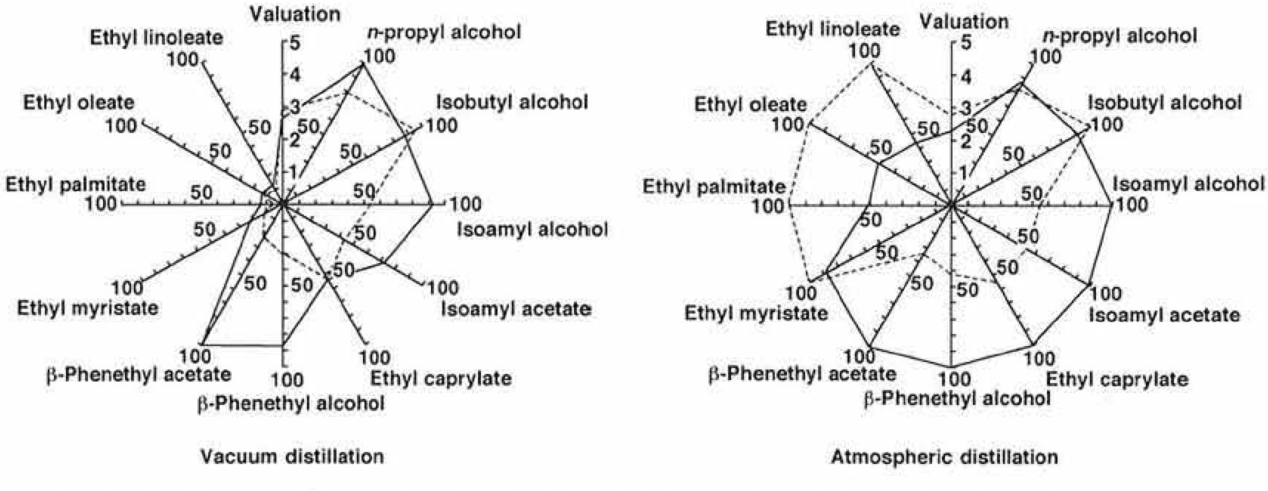

Fig. 6. Sensory test of spirit (25% (v/v)) made by the application of the non-cooking and cooking fermentation methods with the saccharifying enzyme preparation E
—— ; Non-cooking, ------ ; Cooking.

The ratios of the principal aroma and flavor components in the distillate produced by vacuum distillation are shown in Fig. 6. In the sensory test, the value for the product obtained by the non-cooking fermentation method was satisfactory, 2.64 compared with 2.86 for the product obtained by the cooking fermentation method. As mentioned above, these results were due to the high concentration of the flavor components of the products obtained by distillation, and the higher concentrations of the flavor components from the mash in the non-cooking fermentation system compared with the mash in the cooking fermentation system. The product obtained by the cooking fermentation system was of a dry type because the aroma was weak and almost no higher fatty acid esters were detected. In contrast, the product obtained by the non-cooking fermentation system had a good aroma and mild taste because the concentrations of flavor components with low and medium boiling points were higher. The A/B ratio was as high as 2.6 but the taste was rather dry because of the low concentration of higher fatty acid esters.

The ratios of the principal aroma and flavor components of the products obtained by atmospheric distillation are also shown in Fig. 6. Generally, both aroma and flavor components are present in large quantities in spirits distilled under atmospheric pressure, but a product with well-balanced A/B, A/P (isoamyl alcohol/*n*-propyl alcohol) and B/P (isobutyl alcohol/*n*-propyl alcohol) ratios of higher alcohols is preferable[4]. Spirit obtained by the cooking fermentation method had a low A/B ratio (1.34 and 1.32 under vacuum and atmospheric distillation, respectively) because isobutyl alcohol was present in large quantities. However, spirit obtained by the non-cooking fermentation method had a high A/B ratio (2.6 under both vacuum and atmospheric distillation) because isoamyl alcohol was present at higher concentrations. As the product obtained by atmospheric distillation had a slightly increased higher fatty acid ester content than that obtained by vacuum distillation, it was superior to the product obtained by vacuum distillation in terms of roundness to receive an evaluation point of 2.28. This product therefore could satisfy the taste of the public.

It has been stated that the characteristics of the raw materials are well developed in the product obtained by the non-cooking fermentation method[6]. In this study, the product obtained by the non-cooking fermentation method was superior to that obtained by the cooking fermentation method in terms of both aroma and flavor components. The product had a milder taste than that obtained by atmospheric distillation from the second mash in the conventional method. This was due to the low fatty ester content, as shown in Fig. 6 in this paper and Table 5 in the previous report[2]. Therefore, this product received a high evaluation point from the panelists.

4) Conditions used in the case study in the shochu spirit factory

The shochu spirit factory surveyed this time used 630 kg of rice per fermentation, and the proportion of raw materials and water is shown in Table 1. Two workers were engaged in the factory's manufacturing process: 650 L of crude shochu was manufactured from 630 kg of raw materials with an alcohol percentage of 43.5%. Considering that the ordinary percentage of alcohol of distributed shochu is 25%, the value can be converted to 1,131 L of commercialized shochu. Although the case study was carried out under these conditions, the cost calculation will be based on the conversion of actually measured figures 1,131 L into 1,000 L (1,131 L/1,000 L).

Regarding the energy aspect, the amount of water in the boiler, exhaust gas temperature, oxygen concentration in exhaust gas, the amount of heavy oil used, the amount of drain of the koji-making machine and the amount of drain of the distillation machine were measured, and the energy consumption was examined. The total energy consumption required to manufacture 1,000 L of 25% shochu is shown in Table 2. The steam amount in a shochu factory using 630 kg of rice was 656 kcal/kg, and 172 L as A-grade heavy oil.

Two workers were engaged in the manufacturing process and the number of worked hours depending on each process is shown in Table 3. By introducing an automatic koji process machine, the ratio of the koji process which is the most time and labor-consuming process during the manufacture process, decreased to 19.1%. The characteristics of the non-cooking fermentation system removed the processes

Table 1. Proportion of raw materials and water

	First fermentation	Second fermentation	Total
Rice koji	180 kg		180 kg
Rice (main raw material)		450 kg	450 kg
Water	216 L	792 L	1,008 L

Table 2. Ratio of working process and workers[a)]

Manufacturing process	Ratio of process	Workers	Note
Raw material treatment	11.0 (%)	0.22 (person)	Saving of labor 0.75 person × ¥20,000 = ¥15,000 (Raw material treatment, Koji process, First fermentation)
Koji process	19.1	0.38	
First fermentation	7.7	0.15	
Second fermentation	32.0	0.64	
Distillation	18.0	0.36	
Refining & blending	3.6	0.02	
Others	8.1	0.16	
Total	100.0	2.00	

a): Except for bottling process.

Table 3. Consumption of energy for working process and cost

		Current manufacturing process (A)	Manufacturing process in non-cooking fermentation system (B)	(A−B)/(A)	A−B
Amount of energy	Amount of steam	1,851.1 L	1,352.8 L	26.8%	¥2.259
	A heavy oil	172.0 L	125.9 L		
		¥8,428	¥6,169		
Raw materials	Koji fee or enzyme fee	¥24,155	Enzyme ¥4,504 Citric acid ¥4,680 Total ¥9,184	62.0%	¥14,971
Amount of work	Number of workers and personnel expenses	2.00 persons	1.25 persons	37.5%	¥15,000
		¥20,000 × 2.00 persons = ¥40,000	¥20,000 × 1.25 persons = ¥25,000		
Saving			—		¥32,230

of rice steaming, koji-making and the first fermentation stage. Without these processes, 0.75 manpower could be saved. If the daily wage for 1 person is ¥20,000, ¥15,000 can be saved.

The manufacturing cost per 1 kg of koji, including the raw material cost was ¥299, and in this factory the koji cost was ¥53,800. The koji manufacturing cost excluding the raw material cost was therefore ¥24,155. In the non-cooking fermentation system, as mentioned before, enzyme and citric acid were used. The cost of the enzyme was ¥4,504 (1,126 g × ¥4) and that of citric acid was ¥4,680 (1,800 g × ¥2.6).

5) Economic aspects of the introduction of the non-cooking fermentation system into a rice shochu factory

In taking account of the energy consumption and labor force, the present conditions of a medium rice shochu factory were examined. Thereafter the economic effectiveness of the introduction of the non-cooking fermentation system into this shochu factory, was estimated. Since the non-cooking fermentation system is characterized by the elimination of the rice steaming process, energy can be saved and thus manpower in the manufacturing process can also be reduced. Due to the possibility of reducing labor to 38.8% and eliminating the first fermentation stage in the manufacturing process, it was possible to reduce the whole process to half. Based on the results obtained, a comparison between the existing manufacturing system and the non-cooking fermentation system is shown in Table 3. In terms of energy, ¥2,259 could be saved and this figure represented 26.8% of the whole energy cost. Since the koji process could be eliminated, ¥24,173 could possibly be saved. However, a sum of ¥4,504 for enzyme treatment and ¥9,184 for citric acid is necessary in the non-cooking fermentation system. Based on the figures listed above, a total sum of ¥14,471 could be saved. Due to labor-saving, ¥15,000 could be saved resulting in an economic benefit of ¥32,248 in terms of cost-saving. In addition, since the non-cooking fermentation system can be applied to the existing facility, new plant and equipment investment is not necessary. As a result, in the process of manufacturing 1,000 L of 25% alcohol shochu, it was evident that ¥32,248 could be saved, suggesting that ¥58 per bottle of ordinarily distributed 25% shochu could be saved, which amounted approximately to 10% of the cost of shochu production.

References

1) Editorial Committee of Official Methods of Analysis (1974): Official methods of analysis of national tax administration (3rd ed.). Brewing Society of Japan, Tokyo [In Japanese].
2) Kida, K. et al. (1991): Production of shochu from crushed rice by non-cooking fermentation with saccharifying enzyme. *J. Soc. Brew. Jpn.*, **86**, 962-968 [In Japanese with English summary].
3) Kida, K. (1991): Influence of mineral nutrients on high performance during anaerobic treatment of wastewater from a beer brewery. *J. Ferment. Bioeng.*, **72**, 54-57.
4) Nishiya, T. (1980): Aroma and flavour in traditional shochu. *J. Soc. Brew. Jpn.*, **75**, 641-649 [In Japanese with English summary].
5) Nishiya, T. (1983): Qualitative analysis on aroma and flavour of shochu by gas chromatograph. *J. Soc. Brew. Jpn.*, **78**, 275-278 [In Japanese].
6) Shinoki, S. et al. (1987): Shochu making with use of various uncooked cereals. *J. Soc. Brew. Jpn.*, **82**, 651-654 [In Japanese with English summary].
7) Yoshizawa, K. & Ishikawa, T. (1985): Changes of lipids during sake brewing and their contribution to ester formation by yeast. Monograph. *Hakkokogaku*, **63**, 161-171 [In Japanese with English summary].

(Received for publication, May 13, 1998)