Potential Use of Refrigerated Distiller in Improving Quality Consistency and Productivity of Balinese Distilled Drink

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Abstract. In Bali, there is an alcoholic drink that is traditionally distilled by Balinese villagers. The drink is well known as Arrack Bali distilled from fermented sap of palm flower. The use of traditional distillation equipment makes villagers unable to produce the drink with consistent quality. In fact, the demand for the quality is quite high because the drink is already in demand by foreign tourists. With these considerations, it is necessary to develop an affordable machine that is able to produce the Balinese distilled drink with good and consistent quality. This paper presents a local based distillation machine specifically developed for production of the Balinese distilled drink. The machine integrates novelties which comprise a refrigeration distiller and smart controller for both distiller and boiler. The distiller is a coil on tube heat exchanger which can absorb heat of Arrack vapor and condense it in the distiller tube. The distiller tube is cooled by refrigerant R-134A which is flowing in the evaporator pipe that is coiled on the outer surface of the tube. Experimental investigation was established to evaluate the performance of the refrigerated distiller and the boiler of the novel and affordable distillation machine. The results showed that the refrigerated distiller and boiler can perform reliably with several temperature set and production process characteristics. In addition, production test results showed various good quality variants of Arrack Bali could be produced consistently with alcohol content ranging from 20% up to 40% by volume. These variants are resulted from production characteristics at boiler temperature varied from 87 up to 93 °C and refrigerated distiller temperature from 5 to 27 °C and corresponding production time from 1 hour up to 6 hours. Beside the potential to produce good and consistent quality Balinese distilled drink, the novel distillation machine was also found to noticeably improve the productivity of distillation process.

Keywords: Refrigerated Distiller, Consistency, Productivity, Balinese Distilled Drink

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1 Introduction

Arrack is a type of fermented liquor containing 37-60% alcohol (ethyl alcohol) which has been known in Bali since ancient times. Arrack is an alcoholic drink that is used in several ceremonies for cultural and religious activities in Bali. Arrack is generally made from palm sap by distillation. Arrack can also be made from fermented pineapple.

Arrack production in Bali is done traditionally, so it is not clear the alcohol content and the consistency of arrack quality is very difficult to maintain [1,2]. The simple processing process is prone to health problems, especially if it contains methanol, when drunk, it can cause toxic effects on the human body. The misuse of arrack as an alcoholic beverage has been published by the relevant agencies as reported in Depkes RI [3] and Dinas Kesehatan Provinsi Bali [4]. However, within certain limits alcoholic beverages in various countries are permitted or halal to be consumed [5].

Karangasem is one of the places where arrack is produced in Bali. Merita Village, in Karangasem Regency, is a village where almost all of the people process and produce traditional arrack drinks in a home industry and the process is still very simple. The use of simple tools, besides being unable to maintain the consistency and quality of the resulting arrack, they are also inefficient. With simple tools, farmers are only able to produce 10 liters of arrack per day from 60 liters of fermented palm sap. Therefore, it is necessary to have a distillation machine that ensures the consistency of product quality, compliance with health standards and energy efficient.

Arrack Bali is also in great demand by guests from abroad. Recently, Arrack Bali has also given a good economic impact for arrack farmers in Karangasem. Moreover, the attention of the Governor of Bali is very serious about the development of this traditional Balinese drink. It is proven that the Governor of Bali Regulation no. 1 of 2020 has been issued regarding the management of Balinese fermented or distillated drinks, including Balinese Arrack [6]. With the support of the Bali Regional Government and the Bali Governor's belief that Arrack Bali is very effective and useful as a basic ingredient for Covid-19 therapy with a high healing effect. Arrack farmers are increasingly free to produce arrack and their economy is increasing. Therefore, there is a need for a distillation machine based on appropriate technology which ensures consistency of product quality, compliance with health standards and energy efficient. Appropriate technology has technical characteristics, namely it is possible and easy to manufacture, economically affordable, in terms of safety, it is safe to use without disturbing occupational health, is environmentally friendly, energy efficient and in accordance with the progress of the times [7-10]. The applied appropriate technology is expected to have an output with identification of effective, comfortable, safe, healthy, efficient and productive [11-13].

Arrack Bali is fairly high alcohol content, which can reach 37-60%. While Presidential Decree No. 74 [14] concerning the control and supervision of alcoholic beverages has provided limits on alcohol content according to group. Where class A alcoholic beverages are drinks containing ethyl alcohol or ethanol with levels up to 5%. Class B alcoholic beverages are drinks containing ethyl alcohol with a content of more than 5% to 20%. Class C alcoholic beverages are beverages containing ethyl alcohol with a content of more than 20% to 55%. On the other hand, Arrack Bali, which is produced

traditionally, is divided based on the alcohol content into four groups, namely: Grade-1 with more than 30% to 40% alcohol; Grade-2 from more than 20% up to 30%; Grade-3 more than 10% to 20% alcohol [15].

With respect to the quality consistency of the Arrack Bali product, one research has reported that the increase and decrease in the temperature of the distillation process (includes evaporation and condensation) can occur due to poor control or caused by a malfunction of the controller. The effect of decreasing temperature on the quality of the distillation product is the opposite of the effect of increasing the temperature. Lower distillation process temperature can result in reduction the amount or composition of heavier components (lower water content) or intensification the amount or composition of lighter components (higher alcohol content). This also means a bad temperature controller can cause inconsistent distillation product [16]. Therefore, by using a traditional distillation equipment with surely bad temperature controller can be very difficult to produce a consistent quality of Arrack Bali. The challenge, then, appear "Can Arrack Bali be conventionally made with a predetermined alcohol content and with a consistent quality so that the quality is maintained. This paper presents a solution for the challenge appeared.

2 Material and Methods

2.1 The Refrigerated Distillation Machine

The appropriate technology applied on the distillation machine combines the advantages of energy efficient refrigeration technology using the R-134A. The technology is also equipped with a smart control system that is capable to control operational variables automatically.

The control variables include evaporation temperature of the arrack raw materials in the boiler, temperature of condensation in the refrigeration distiller and the time or duration of the distillation process in one filling of the fermented palm sap raw material in the boiler. The evaporation temperature in the boiler is controlled in the ethanol evaporation range of above 78.4 °C. Then it is followed by controlling the temperature of the refrigeration distiller to start the process of condensing Arrack Bali. If condensation is carried out firstly, there is a possibility that methanol can be obtained in Arrack Bali and this is not good for human health because its metabolic derivatives are toxic. The control variable settings can be profiled until the characteristics of the production process are found that are suitable to get the quality of Balinese Arrack to meet the quality of industrial products.

The refrigeration technology applied in the machine is optimally utilized both on the side of heat absorption in the evaporator and heat rejection in the condenser. The refrigeration system evaporator is used to cool the distiller so that the arrack vapor can condense and flow into a storage bottle. The distillation machine is shown in Fig. 1.

Fig. 1. The established distillation machine completed with refrigerated distiller, smart controller and large boiler tank

3 Methods

The method applied is an experimental study. This research was initiated by conducting a survey with the community of Balinese arrack farmers and potential users of technology to obtain secondary data about the production process, product type and quality, including product consistency. A survey was also conducted to obtain the characteristics of Balinese Arrack which can be used as the basis for Covid-19 therapy.

Simulation methods with inventor and EES (engineering equation solver) were also applied to simulate the design of the distillation machine and its components as well as simulation of machine performance based on secondary data. Furthermore, the performance calculation was performed using the primary data from the test results. The prototype of the distillation machine was made and carried out function testing and testing the characteristics of the production process with various conditions of control variables. Primary data from testing is recorded and processed to obtain a production process that is consistent and in accordance with the quality target of Arrack Bali which is appropriate of being an industrial commodity and as a basic ingredient for Covid-19 therapy. The content of alcohol in the arrack Bali was measured using a handheld refractometer with accuracy of ±0.20%. The tool is completed with automatic temperature compensation so that it is much easier to be used.

4 Results and Discussion

4.1 Novelties of the Machine

One of the novelties of the distillation machine is the refrigerated distiller. This distiller can perform its function to change the form of arrack vapor from the boiler into arrack

because it is cooled by the refrigeration system. In Fig. 2 it can be seen that the distiller tube made of stainless steel is wrapped around a copper pipe which is the evaporator of the refrigeration system. On the inside of the distiller tube is equipped with a kind of baffle that slows down the flow of arrack vapor. These baffles are connected to the shell of the distiller so that they are also cooled down. So, the baffle in addition to slowing the flow also expands the contact area with the hot arrack vapor. Such constructions increase the effectiveness of the distiller.

The integrated distiller is also part of the refrigeration system of the distillation machine. The evaporator of the refrigeration system is wound on the outer surface of the distiller. After absorbing heat from the distiller in this case the heat from the arrack vapor, then this heat is rejected in the condenser. The heat from the condenser is discharged to the outside air. The performance of the refrigeration system applied in the distillation machine is not included in this paper. Its performance certainly varied to follow fluctuation of the evaporation temperature in the evaporator and condensation temperature of the condenser as discussed in [17-19].

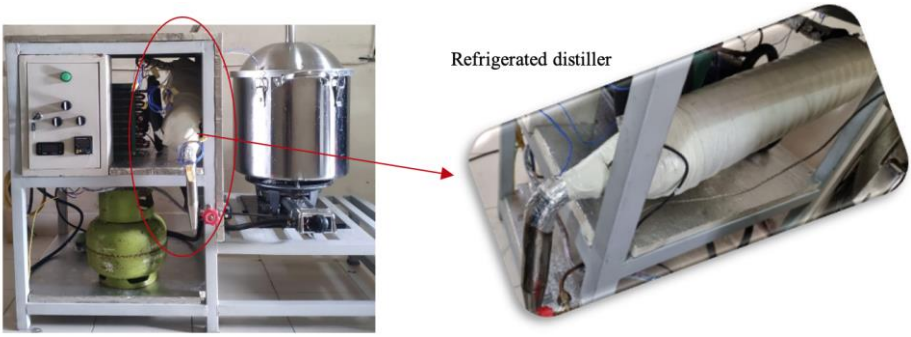

Fig. 2. Refrigerated distiller

The novelty shown in this machine can make the machine more compact compared to distillation machines that use air cooling or water cooling. In addition, the stainlesssteel material used, it can ensure the cleanliness and hygiene of the arrack product. By adjusting the cooling temperature combined with the heating temperature setting in the boiler, it can provide a variety of arrack products according to market needs. The ability to maintain the operating temperature of the distiller and boiler can increase the novelty of the distillation machine because it is able to maintain the consistency of the quality of the product.

4.2 Operation and Controlling Reliability

Setting and maintaining the temperature level on the two main components (distiller and boiler) of the distillation machine is carried out by an intelligent control system located in the electrical control panel (Fig. 3). The intelligent control system consists of: (i) Distiller temperature controller which functions to maintain and regulate the con-

densation temperature of the arrack vapor in the distiller; (ii) Boiler temperature controller which is maintaining and regulating the evaporation temperature of the raw material of arrack (fermented sap) into vapor.

Fig. 3. Smart controller

The controller for the distiller works based on a temperature sensor mounted on the distiller body. This sensor provides a temperature level signal from the distiller as input. Based on this input, the controller then responds in the form of an "On or Off" signal to the refrigeration system. If the temperature level is already achieved, then the compressor of the refrigeration system is made "Off" and vice versa.

For the boiler controller, a temperature sensor is immersed in the fermented sap. This sensor provides information to the controller of the temperature level of the evaporation process that occurs in the boiler. The controller closes the fuel supply valve to the burner and turn off the burner (but the pilot flame remains on) when the temperature of the evaporation in the boiler has reached the setting temperature. Based on the regulatory capabilities provided by the two controllers, the Distillation Machine can perform intelligent controls in maintaining the consistency of operational conditions which affect the product quality. By using the intelligent control, the machine is able to provide various variants of the quality of the Arrack Bali. The controller can also ensure that the evaporation temperature in the boiler is 78.4 °C or above. Therefore, only ethanol is produced as reported in [20].

4.3 Characterization of the Balinese Distilled Drink Production

The machine incorporates novelties which include a refrigerated distiller and smart controller for both boiler and distiller. The machines can perform reliably with several production characteristics. Fig. 4 shows one of the characterizations of the Arrack Bali production utilizing the distillation machine. The figure shows the operational characteristics of 7 hours continuous production. From the figure it can be seen that the machine can stably maintain boiler and distiller temperatures where the raw material was boiled and condensed respectively.

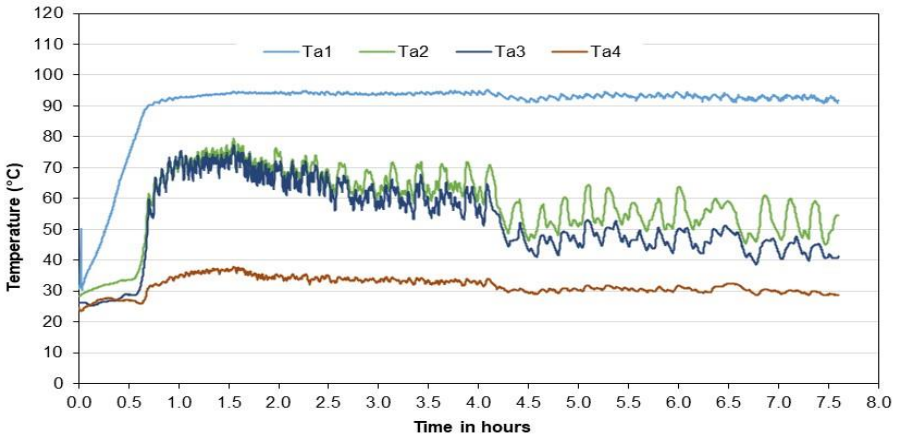

Fig. 4. Temperature characterization of the arrack Bali production from boiler (T_{a1}), connecting pipe (T_{a2}), entering distiller (T_{a3}) and exiting the distiller (T_{a4}) or to storage bottle

The temperature condensation in distiller is estimated by using temperature at the inlet (T_{a3}) and outlet (T_{a4}) of the distiller with average ranging from 25 to 50 °C. Temperature drop occurs along the connecting pipe from boiler to the distiller for about 20-30 K. This temperature drop is not only due to heat losses across the connecting pipe but also due to heat absorbed by the evaporator of the refrigeration system in the distiller. The fermented sap temperature in the figure refers to initial temperature of the raw material in the boiler tank. The temperature condensation in distiller is estimated by using temperature at the inlet (T_{a3}) and outlet (T_{a4}) of the distiller with average ranging from 25 to 50 °C. Temperature drop occurs along the connecting pipe from boiler to the distiller for about 20-30 K. This temperature drop is not only due to heat losses across the connecting pipe but also due to heat absorbed by the evaporator of the refrigeration system in the distiller. The fermented sap temperature in the figure refers to initial temperature in the boiler tank.

Refrigeration temperature applied to drive the refrigerated distiller is shown in Fig. 5. It can be seen clearly that the refrigeration system which comprising 1/4 Pk condensing unit could maintain the temperature with regular cycle On and Off. This means the refrigeration system can reach the set point of 5 °C during the production period. The temperature variation shown in Figure 5 also indicates the refrigerated distiller is reliable to condense the arrack vapor during the production process (where T_1 = temperature refrigerant entering the compressor or exit the distiller, T_2 = temperature at discharge compressor, T_3 = temperature at exit of the condenser and T_4 = refrigerant temperature entering the evaporator or distiller).

The machines can perform reliably with several production characteristics. The machine is capable to consistently produce several variants of Arrack Bali which can be grouped into four grades: Grade-Super, Grade-1, Grade-2 and Grade-3 with alcohol content above 40%, 30%, 20%, 10% respectively. These variants are resulted from production characteristics at boiler temperature 87-95 °C, distiller temperature from -5 to 30 °C and corresponding production time 0-1, 1-2, 2-3, and 3-6 hours respectively as

shown in Table 1. In this study, the grouping and grading of Arrack Bali products were developed to accommodate the grouping carried out by arrack farmers as reported [15] and to comply with Presidential Decree No. 74 [14].

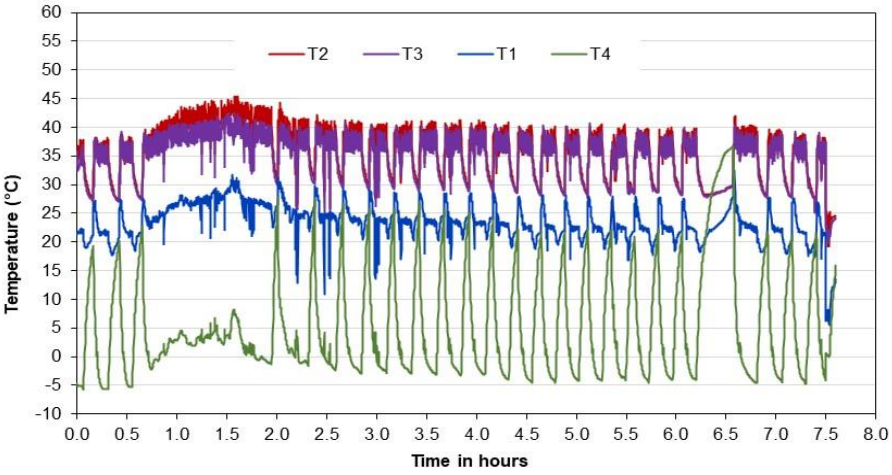

Fig. 5. Refrigeration temperature characterization of the refrigerated distiller

Table 1. Balinese distilled drink product grades and characteristics

Production parameters	Arrack Bali Product Grade			
	G-S	G-1	G-2	G-3
Boiler temperature (°C)	87-95	87-95	87-95	87-95
Distiller temperature (°C)	-5 to 27	-5 to 27	-5 to 27	-5 to 27
Time of production (hours)*	0 -1	1-2	2-3	3-6
Volume (L)	0.34	0.31	0.30	0.90
Alcohol content (%)	42	34	29	15
Productivity (mL/hour)	340	310	300	300
Energy use intensity (kWh/L)	3.01	3.31	3.42	3.42

Alcohol content of each grade: Grade Super (G-S) >40%-50%; Grade-1 (G-1) >30%-40%; Grade-2 (G-2) >20%-30% and Grade-3 (G-3) >10%-20%; *Time of production including time required for initial process of distillation about 20-30 minutes.

4.4 Productivity and Energy Performance

With respect to the energy performance and productivity, test results showed the machine could produce Arrack Bali of Grade-Super (G-S) for about 340 mL per hour with energy consumption per liter Arrack Bali Grade-Super of about 3.01 kWh. More detailed energy use intensity and productivity of the machine with other variants of Arrack Bali products can be seen in Table 1. The energy use intensity increases when the alcohol content decreases. This means that for producing lower grade of Arrack Bali would require more energy. This is caused by the more water content that must be evaporated

and condensed where water has a higher temperature and energy of evaporation or condensation than alcohol. The energy use and productivity of the developed distillation machine cannot be compared with the existing traditional machines used by the farmers because there are no publications as yet that present energy use and productivity of the traditional distillation machines. The energy use may be difficult to measure due to the use of biomass with traditional cooker as its boiler. By using the proposed distillation machine with refrigerated distiller, the production can be repeated with the same operational characteristics and with consistent product quality.

5 Conclusion

A novel distillation machine specifically designed for Arrack Bali production has been developed and tested. The machine incorporates novelties which include a refrigeration distiller, preheating heat exchanger and smart controller for both boiler and distiller. The machines can perform reliably with several production characteristics. Production test results showed several variants of Arrack Bali could be produced consistently. Four grades of Arrack Bali can be produced using the machine which include Grade-Super, Grade-1, Grade-2 and Grade-3 with alcohol content above 40%, 30%, 20%, 10% respectively. The product variants are resulted from production characteristics at boiler temperature at boiler temperature 87-95 °C, distiller temperature from -5 to 27 °C and corresponding production time the first 1 hour, the second 1 hour, the third 1 hour, and the fourth stage of 3 hours. The machine could produce Arrack Bali of Grade-Super for about 340 mL per hour with energy consumption per liter Arrack Bali Grade-Super of about 3.01 kWh. The energy use intensity tends to increase when producing lower grade of Arrack Bali.

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References

1. N.P. Widya Astuti, N.M. Suaniti, dan I.G. Mustika, “Validasi metode dalam penentuan kadar etanol pada arrack dengan menggunakan kromatografi gas detektor ionisasi nyala”, Jurnal Kimia **11**(2), 128-133 (2018).
2. N.M. Suaniti, I.A.R. Astiti Asih, N.P. Widya Astuti, “Deteksi Etanol setelah Konsumsi Arrack dalam Urin dengan Gas Chromatography”, Jurnal Kimia **6** (2), 112-115 (2012).
3. Depkes RI, “Bahaya Minuman Beralkohol Bagi Kesehatan”, (2017), available from: www.depkes.go.id (accessed 15 August 2022).

4. Dinas Kesehatan Provinsi Bali, "Laporan Kejadian Keracunan Minum Arrack, Bali: Dinas Kesehatan Provinsi Bali", (2014).
5. A. Najiha, dan W.A. Nadiah, "Alkohol (Arrack dan Etanol) dalam Makanan Halal", Jurnal Intelek **9**(1), 40-51 (2014).
6. N.L. Rhismawati, "Gubernur Bali terbitkan pergub soal tata kelola arrack Bali", (2020), https://bali.antaranews .com/berita/179051/gubernur-bali-terbitkan-pergub-soal-tata-kelola-arrack-bali (accessed 21 August 2022).
7. I. Zelenika, and J.M. Pearce, "Barriers to Appropriate Technology Growth in Sustainable Development", Journal of Sustainable Development **4**(6), 12-22 (2011).
8. I. Zelenika, and J.M. Pearce, "Innovation Through Collaboration: Scaling up Solutions for Sustainable Development", Environ. Dev. Sustain. **16**(6), 1299-1316 (2012).
9. J.M. Pearce, "The case for open source appropriate technology", Environ. Dev. Sustain. **14**, 425–431 (2012).
10. J.M. Pearce, S. Albritton, G. Grant, G. Steed, and I. Zelenika, "A new model for enabling innovation in appropriate technology for sustainable development", Sustainability: Science, Practice, & Policy **8**(2), 42-53 (2014).
11. H. Shin, J. Hwang, H. Kim, "Appropriate technology for grassroots innovation in developing countries for sustainable development: The case of Laos", Journal of Cleaner Production **232**, 1167-1175 (2019).
12. J. Patnaik, and B. Bhowmick, "Revisiting appropriate technology with changing socio-technical landscape in emerging countries", Technology in Society **57**, 8-19 (2019).
13. A.S. Boakye-Ansah, K. Schwartz, M. Zwarteveen, "Aligning stakeholder interests: How 'appropriate' technologies have become the accepted water infrastructure solutions for low-income areas", Utilities Policy **66**, 101081 (2020).
14. Presidential Decree No. 74, "Presidential Regulation of the Republic of Indonesia concerning control and supervision of alcoholic drinks", (2013).
15. P.A. Indrayathi, N.L.P. Suariyani, I.M. Subrata, R. Noviyani, "Persepsi produsen arrack di desa merita, karangasem mengenai bahaya keracunan arrack oplosan yang mengadung metanol yang dapat mengancam kesehatan dan pariwisata di Bali", (2021), available at: https://simdos.unud.ac.id/uploads/file_penelitian_1_dir/b791d1b05297a9db7aef5ae804c30153.pdf
16. I.G.K. Sukadana, and I.G.N.P. Tenaya, "Performansi mesin berbahan bakar etanol hasil destilasi arrack Bali", Jurnal Energi dan Manufaktur **9**, 70-74 (2016).
17. I.N. Suamir, I.N.G. Baliarta, M.E. Arsana, I.W. Temaja, "The Role of Condenser Approach Temperature on Energy Conservation of Water Cooled Chiller", Advanced Science Letters **23**(12), 12202-12205 (2017).
18. I.N. Suamir, I.N.G. Baliarta, M.E. Arsana, I.P.S. Negara, "Condenser-Evaporator Approach Temperatures and their Influences on Energy Performance of Water Cooled Chillers", Proc. the 14th International Conference on QIR (Quality in Research) at: Mataram, Lombok, Indonesia (2015), 428-433.
19. I.N. Suamir, I.N.G. Baliarta, M.E. Arsana, Sudirman, I.M. Sugina, "Field-based Analyses on Approach Temperatures for Performance Evaluation of Centralized Air Conditioning System in a Shopping Mall Building", Journal of Physics Conference Series **1569**, 032041 (2020).
20. J.A. Kraut, and I. Kurtz, "Toxic alcohol ingestions: Clinical features, diagnosis, and management", Clinical Journal of the American Society of Nephrology **3**(1), 208-225 (2008).