PLC Rice Series: Low-Protein Rice Products

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Summary  Dietary therapy through a low-protein diet (LPD) has long been used for preserving the renal function of patients with chronic kidney disease (CKD). Reducing the amount of protein ingested from rice would make it possible to allocate the difference to side dishes, thereby improving the quality of meals and facilitating adherence to LPD. If it is possible to remove protein from rice, it would minimize the need to cut down on main dishes and make it easier for patients to follow the LPD. We developed exclusive technology for digesting and removing protein from rice grain using microorganism-derived enzyme product, and technology for processing the Low-Protein Rice (LPR) thus obtained into a palatable food product. By combining these technologies, we can reliably manufacture delicious, high quality, low protein rice product, which can be eaten repeatedly as staple. Our LPR products, “PLC Rice” series are helpful to enhance the quality of mealtimes for CKD patients by increasing their range of food choices. It is therefore reasonable to say that PLC Rice products offer high added value, as it not only facilitates adhesion to LPD but also add satisfaction and contentment to daily meals, helping to enhance the quality of life of patients with CKD.

Key Words  chronic kidney disease, low protein diet, low protein rice

Dietary therapy through a low protein diet (LPD) has long been used to preserve the renal function of patients with chronic kidney disease (CKD) (1–3). LPD restricts the amount of protein in the total food intake and it lowers the production of urea nitrogen, an end product of protein metabolism (4). It is considered that the level of protein intake modulates the filtration load on the kidneys and tempers the decline of renal function (5, 6). Over the past 50 y, LPD have been successfully used to treat chronic renal failure in Japan (7). From clinical findings, the recommended protein intake for Japanese CKD patients is under 0.5 g/kg BW/d (8). According to this, a patient weighing 60 kg should ideally ingest less than 30 g of protein per day. If the patient eats a bowl (approximately 165 g) of cooked rice 3 times a day, he/she will ingest 12.5 g of protein from the rice and it would account for 40% of the protein allowance. To keep with the allowance, the entire meal plan needs to be adjusted. Since the easiest course of action is to cut down on foods which are high in protein, the main dishes, such as meats and fish, are usually reduced to smaller servings. Such frugality compromises the quality of mealtimes and makes patients difficult to adhere to the LPD, and as a result, be unable to reap the benefits of LPD.

Removing protein from rice grain would minimize the need to cut down on main dishes. Mealtime quality would be maintained, making it easier for patients to follow the LPD. To address this issue, in 1992 the Niigata Agricultural Research Institute Food Research Center developed technology (JP2706888B) using lactobacillus fermentation to reduce the protein, phosphate, and potassium contained in white rice (WR) (9). However, their method posed technical challenges such as extremely long processing times and the difficulty of microorganism control hampering reliable production.

In 1994, Forica Foods Co., Ltd. (Niigata, Japan) built on this technology to develop an exclusive proteolysis technology (JP3156902B) utilizing an enzyme product which can break down protein in WR more quickly and reliably than lactobacilli fermentation (10). The following year, the manufacture and sales of “Cooked PLC Rice 1/3 (PLC: Protein Low Content)” began.

PLC Rice is processed, protein reduced WR. The palatability (quality) of this low protein rice (LPR) is such that it can be eaten day after day. The PLC Rice products were developed to facilitate adhesion to the LPD, thereby improving the quality of life (QoL) of patients with CKD. In this document, the manufacturing process for the PLC Rice series will be described.

Materials and Methods

Overview of Manufacturing method

The manufacturing flow of these products is outlined in Fig. 1. Regardless of product form, low protein rice products need to have their rice protein content broken down and removed. The method employed by Forica Foods Co., Ltd. is based on the invention by Nakajo et al. (JP3156902B), and consists of utilizing protease to

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Abbreviations: CKD: chronic kidney disease, LPD: low-protein diet, LPR: low-protein rice, QoL: quality of life, WR: white rice.
process protein (10).

**Raw materials**

Raw materials of LPR are WR, pH adjuster, and proteolytic enzyme. There is no particular restriction on varieties of WR, either Japonica rice (short grain) or Indica rice (long grain) can be used. To control pH, a suitable quantity of organic acid can be added (e.g. citric acid, lactic acid, fumaric acid, gluconic acid, and glucono delta-lactone). Out of these, citric acid (CA) is chosen because of its high buffering properties, ability to maintain pH within the enzyme solution stably over a long period, and for having the smallest negative effect on the taste and aroma of cooked rice.

As proteolytic enzyme, acidic protease approved by the Ministry of Health, Labour and Welfare as a food additive and available on the market is used. Each enzyme product is a crude enzyme product extracted from the source microorganisms (e.g. *Aspergillus oryzae*, *Rhizopus niveus*, and *Aspergillus niger*), and the main component is protease in the aspartic protease family (EC 3.4.23).

**Protein digesting process**

The protein digesting process is broadly divided into enzyme digestion and washing. In the first step, surface bran residue and germs are washed away with water. The washed WR is placed in a reaction solution containing dissolved enzyme mix (EM) consisted by some of avobe and CA, and allowed to soak for a certain period of time (up to 24 h) in a temperature and pH conducive to enzyme activity. This breaks down the protein in the WR. Subsequently, thorough water washing removes any unnecessary matter: rice protein decomposition product, EM, and excess CA.

Figure 2 shows the time lapsed changes of protein mass in rice treated with enzyme with a single protease derived from *Aspergillus oryzae*. Protein mass in rice is highly dependent on enzyme concentration and reaction time. By adjusting these factors, the rice protein mass can easily be reduced to target levels. In the actual process of protein enzyme treatment, EM is used

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**Fig. 1.** Production flow chart of PLC Rice.

**Fig. 2.** The effect of processing time and enzyme concentration on protein removal.

**Fig. 3.** The overview of PLC Rice products.
instead of a single enzyme, resulting in better removal rates and production efficiency compared to a single enzyme. This is likely to be because the combination of multiple enzymes each with different protein cleavage sites reduces the molecular weight of the decomposition product. The smaller the molecular weight of rice protein, the easier it is to elute from the rice grain.

Cooking method

These steps yield LPR (Raw LPR), which is raw, protein reduced WR. Processing the Raw LPR requires special techniques and know-how to maintain their shape while offering palatability. This is because Raw LPR grains are extremely fragile, and when subjected to steaming or cooking like ordinary WR, they dissolve into a gruel-like mass which is far from delicious. In order to solve this problem, we developed a method (WO 2017037799 A1) for processing LPR into a palatable, high quality product (II).

Results

Product overview and their nutrition

PLC Rice series are LPR products which are processed, protein reduced WR (Fig. 3). Nutrition information on PLC Rice products is shown in Table 1. Test samples were taken from at least three separate production days. As shown in the Table, there is minimal interlot variability of nutritional values, indicating extremely high reproducibility. Particularly noteworthy is the protein content, which demonstrates reliability in meeting the respective target values.

Microbiological safety of product

To store the packaged “Cooked PCR Rice” safely in room temperature, the contents must be sufficiently sterilized and sealed in the sterile state. Raw LPR is steamed with high temperature, high pressure steam in a steaming device installed in a clean room. At the same time, it undergoes thorough sterilization under conditions which are equivalent to the 120°C for 4 minutes (F0 = 3.1) stipulated in the Japanese Food Sanitation Act for retort pouch food. Subsequently, the contents are kept sterile while sealing together with oxygen absorber, thereby securing sterility of the product. In fact, since its adoption in 2004, there have been no incidents of product spoilage or deterioration attributable to insufficient sterilization, proving the efficacy and safety of this technique.

According to our findings relating to “Pre-Cooked PLC Rice,” drying steamed LPR to a moisture content of 15 to 26% yields desirable quality (particularly mouth-feel) when it is cooked. By sealing this together with oxygen absorber and maintaining an anaerobic state inside the package, it becomes possible to store it safely at room temperature. However, once the package is opened, new oxygen flows into the package. The anaerobic state cannot be maintained and there is risk of mold and other microbiological growth. A product with moisture level higher than 20% requires refrigeration or freezing. However, a product dried to a moisture level of 16 to 20% can be stored safely at room temperature. This is due to the reduced water activity of the product, which prevents mold etc. from proliferating after the package is opened.

Product safety and Quantities manufactured

In more than 20 y since its launch, nearly 100 million PLC Rice products have been provided to CKD patients through many hospitals throughout Japan. In these two decades of producing and selling PLC Rice series, there have been no reports of health problems attributable to these products. Given the high frequency of LPD Rice ingestion by CKD patients who eat it every day as part of their LPD, and the fact that PLC Rice products are composed almost entirely of natural ingredients derived from WR, it is reasonable to say that PLC Rice, regardless of product form, is safe to eat and has no negative health effects, even for CKD patients who ingest them repeatedly over the long term.

Discussion

One of the benefits of a low-protein diet is the preservation of the kidney function (12). Distinct mechanisms could be identified: (i) improvement of hyperphosphatemia and hyperkalemia, (ii) decrease in urinary pro-

| Content       | Unit | WR | Nutrient content in 100 grams of “Cooked PLC Rice” products (Mean±SD) |
|---------------|------|----|-----------------|
| Calories      | kcal | 168| “1/3”           |
| Moisture      | g    | 60.0| 160±3.1         |
| Total Protein | g    | 2.5| 162±6.8         |
| Total Fat     | g    | 0.3| 60.1±1.7        |
| Total Carbohydrate | g | 37.1| 60.1±0.8        |
| Ash           | g    | 0.1| 60.5±1.6        |
| Sodium        | mg   | 0.1| 0.6±0.1         |
| Potassium     | mg   | 0.7| 0.5±0.1         |
| Calcium       | mg   | 0.2| 0.1±0.1         |
| Phosphorus    | mg   | 3  | 0.0±0.1         |

Table 1. Nutrient content in 100 grams of “Cooked PLC Rice” products.
tein, (iii) improvement of subjective symptoms, (iv) prevention of complication, (v) good control even after indication of hemodialysis for better survival (13). As described above, the recommended protein intake for Japanese CKD patients is under 0.5 g/kg BW/d from clinical findings (8). To keep with this recommendation, the entire meal plan needs to be adjusted. Since the easiest course of action is to cut down on foods which are high in protein, the main dishes, such as meats and fish, are usually reduced to smaller servings. Such frugality compromises the quality of mealtimes and makes patients difficult to adhere to the LPD, and as a result, be unable to reap the benefits of LPD.

Substituting white rice by LPR is beneficial for Japanese people because it is easy to reduce the protein intake without changing dietary habit. Figure 4 shows the how different proportions of a hypothetical patient’s daily protein allowance of 30 g is taken up by eating the same 165 g (1 serving) of WR or PLC as the staple food 3 times a day. Unprocessed WR translates to roughly 40% of the daily protein allowance, thereby leaving only about 60% to be allocated to side dishes. By contrast, LPR, even at the reduction rate of 1/3, only accounts for 8.4% of the daily allowance, leaving more than 90% to be occupied by other dishes. The smaller the reduction rate, the less protein from the staple, thereby permitting the rest of the allowance to be filled by other foods. This greatly expands the patient’s food choices.

Another dietary consideration for CKD patients is the desirability of reducing phosphorus and potassium intake in addition to protein. At the same time, there is a need to ensure the patient takes in enough nutrients, particularly energy. With PLC Rice products, not only can protein intake be reduced to the desired level, but the products contain 50% less phosphorus and 95% less potassium compared to regular cooked rice while offering the same energy as WR (Fig. 4) (14). PLC Rice series satisfy the requirements of containing enough energy source and low protein, low potassium and low phosphate as “Medical rice” for CKD patients (13, 14).

We developed exclusive technology for digesting and removing protein from WR using microorganism-
derived enzyme product, and technology for processing the Raw LPR thus obtained into a palatable food product. By combining these technologies, we can reliably manufacture delicious, high quality, low protein rice product, which can be eaten repeatedly as staple. In the 20 y from its launch, nearly 100 million PLC Rice products have been sold, with zero complaints relating to health problems arising from their consumption to date (15). This demonstrates their safety even when eaten repeatedly over a long period.

Our LPR products, “PLC Rice” series which compare favorably with, and can be substituted for, regular rice, are delicious (high quality) enough to be eaten every day. And they are helpful to enhance the quality of mealtimes for CKD patients by increasing their range of food choices. It is therefore reasonable to say that PLC Rice products offer high added value, as it not only facilitates adhesion to LPD but also add satisfaction and contentment to daily meals, helping to enhance the quality of life of patients with CKD.

Disclosure of State of COI
Among authors, N. Takei and N. Watanabe are employees, and M. Nakajo is an executive officer of Forica Foods Co., Ltd. All this study and work has been performed at the Forica Food Co. Ltd.

Acknowledgments
The authors appreciate to Dr. Shaw Watanabe (Life Science Promoting Association, Tokyo, Japan) for his advices on this study. The authors also deeply appreciate The 3rd International Symposium on Rice Science in Global Health, which was held in Kyoto from November 29 to 30, 2018.

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