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Diabetes & its Complications

A Comparative Study of the Effects of Two Rice Products on the Blood-Glucose, Blood Pressure and General Wellbeing of Type II Diabetes Mellitus Patients in the Bo Government Hospital

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ABSTRACT

The rising prevalence of diabetes among active populations across the world is becoming a major public health concern, especially in low and middle-income countries having a heavy dependence on starch-based diets. These countries usually face a problem of limited access to pharmaceutical products which tend to be relatively expensive. Thus, a diet-based approach can be a more plausible option for the management of type II diabetes. Recent clinical studies, mainly involving animal trials suggest that continuous intake of germinated brown rice (GBR) products can provide a cheaper approach in the management of several chronic diseases, including Diabetes Mellitus. To validate these claims in relation to type II diabetes care a pilot clinical trial involving twenty (20) diabetes patients (subjects) was conducted in the Bo Government Hospital, Sierra Leone. A double-blind parallel arm clinical trial involving two groups of type II diabetic subjects put on a continuous diet of normal parboiled brown rice (PBR) and parboiled germinated brown rice (PGBR) was conducted over a period of 4 months. Three sets of data were collected to compare the effects of PGBR and PBR diets on the blood glucose levels, blood pressure, body mass index (BMI) and general well-being of participating subjects. The acceptability of rice treatments was also determined through continuous subjective evaluations conducted over the course of the trial. The results show positive effects from both treatments in relation to all indicators considered. However, PGBR appeared to have a greater effect than PBR in terms of the depression of blood glucose (27.8 and 5.7) systolic (12.7 and 2.9) and diastolic blood pressure (13.6 and 3.6), BMI (4.69 and -1.21), and general wellbeing of the subjects respectively. The study further suggests that the acceptability of both products (PGBR and PBR) was similar and very high (≥ 97.4% for both treatments). While the results obtained in this study corroborate the growing evidence supporting the use of germinated rice products as alternatives to diabetes management and care.

Keywords

Diabetes, Germinated Brown Rice, Parboiled Brown Rice, Parboiled Germinated, Brown Rice.

Introduction

Diabetes is a major public health problem that is approaching epidemic proportions globally. Worldwide, the prevalence of chronic, noncommunicable diseases is increasing at an alarming rate. About 18 million people die every year from cardiovascular disease, for which diabetes and hypertension are major predisposing factors. Today, more than 1.7 billion adults worldwide are overweight, and 312 million of them are obese [1]. The prevalence of Diabetes is increasing worldwide year after year, presenting Health Care Practitioners and Nutritionists with the challenge of identifying ways for effective management of Glycaemia (i.e., maintaining blood glucose level within the normal range). Control and maintenance of postprandial blood glucose levels are very important in the management of Diabetes, especially Type II Diabetes, which is the most common form of Diabetes. About 90 to 95% of people with Diabetes suffer Type

II Diabetes [2]. Growing evidence suggests that if a reduction in postprandial glycaemia is to be part of the strategy to prevent and control Diabetes and Cardiovascular diseases, the Glycaemic Index (GI) is as relevant as the quantity of carbohydrate. Low-GI foods may reduce the insulin demand, improve blood glucose control, reduce blood lipid concentrations and body weight and also help prevent Diabetes-related cardiovascular events. Researchers have proved that nutrition and lifestyle approaches can also play a major role in delaying or preventing the onset of Diabetes.

The world prevalence of diabetes among adults (aged 20–79 years) will be 6.4%, affecting 285 million adults, in 2010, and will increase to 7.7% and 439 million adults by 2030. Between 2010 and 2030, there will be a 69% increase in numbers of adults with diabetes in developing countries and a 20% increase in developed countries [3]. In the African Region, there are still more deaths from infectious diseases than non-communicable diseases (NCDs). Even there, however, the prevalence of NCDs is rising rapidly and is projected to cause almost three-quarters as many deaths as communicable, maternal, perinatal, and nutritional diseases by 2020, and to exceed them as the most common causes of death by 2030 [3].

WHO projections show that NCDs will be responsible for a significantly increased total number of deaths in the next decade. NCD deaths are projected to increase by 15% globally between 2010 and 2020 (to 44 million deaths). Data obtained by Kamara, et al., [4] reveals that over 350,000 Sierra Leonean mostly adults are diabetic representing about 6% prevalence of the disease in the population [4]. This high prevalence of Type II Diabetes in most African countries, including Sierra Leone; might be due to the high dependence of majority of the population on starchy staple food especially rice with minimal consumption of other food nutrients. Significant proportion of rice's imported and consumed in Sierra Leone are from Thailand, Pakistan, and other Asia countries and are considered fast digesting, making it consumption unsuitable especially in individuals with type II diabetes. The key principle here is that the lower the rate of carbohydrate absorption from ingested food, the lower will be the glucose response (postprandial increment in blood glucose level) and therefore the lower the GI value [and *vice versa*] [5]. Rice varieties with slower digesting starch have beneficial attribute to prevent and treatment of disease such as Diabetes, Insulin Resistance, Obesity, Cardiovascular Disease and some type of Cancer. This is because the rate at which starch is digested is linked to blood glucose levels [6].

Germinated brown rice is a novel rice product with enhanced nutrients required for good health. This improvement is possible because in the production of germinated brown rice (GBR), viable rice grains subjected to germinated treatment undergo breakdown of high molecular weight polymers, leading to significant changes in the texture and flavor of brown rice [7]. This is so because the process of germination breaks down complex polymers within the rice grain, making its nutrients more readily available to the body while also improving its texture and flavor compared to regular brown rice; this is primarily due to the increased production of beneficial compounds like gamma-aminobutyric acid (GABA) during the germination phase. This way, it resolved the problems associated with the cooking of brown rice. GBR is considered as a functional food because it aids digestion and absorption of food and contains high amount of nutrients such as gamma-amino butyric acid (GABA), ferulic acid compared to ordinary brown rice. Dried GBR offers an excellent appearance, improved shelf life and handling ease unlike white rice, GBR provides more sweetness, excellent taste, has better texture and is easier to cook. It is concluded that germinated brown rice has the potential to become innovative rice product by preserving all nutrients in the rice grain for human consumption in order to create the highest value from rice. GBR is different from normal brown rice in that it has undergone the process of germination, more specially; the rice embryo is sprouted under suitable environmental conditions [7].

Problem Analysis

According to the WHO [8] Diabetes is a chronic, metabolic disease characterized by elevated levels of blood glucose (or blood sugar), which leads over time to serious damage to the heart, blood vessels, eyes, kidneys and nerves. The most common is type 2 diabetes, usually in adults, which occurs when the body becomes resistant to insulin or doesn't make enough insulin. In the past 3 decades the prevalence of type 2 diabetes has risen dramatically in countries of all income levels. Type 1 diabetes, once known as juvenile diabetes or insulin-dependent diabetes, is a chronic condition in which the pancreas produces little or no insulin by itself. For people living with diabetes, access to affordable treatment, including insulin, is critical to their survival. There is a globally agreed target to halt the rise in diabetes and obesity by 2025 [8].

About 830 million people worldwide have diabetes, the majority living in low-and middle-income countries. More than half of people living with diabetes are not receiving treatment. Both the number of people with diabetes and the number of people with untreated diabetes have been steadily increasing over the past decades [8].

Rice which is a starchy staple food is consumed in almost all meals in Sierra Leone. Most of the rice imported and consumed in Sierra Leone is considered fast digesting which increases the glucose level in the blood. The increasing prevalence of Type II Diabetes Mellitus hereby increasing social costs combined with the fact that the disease is associated with increased morbidity and mortality emphasizes the importance of effective Diabetes management and care [8].

Germinated Brown Rice is a functional food because it is good in digestion and absorption and contains nutrient such as gamma-amino butyric acid, ferulic acid and magnesium which have known health benefits [7]. The beneficial component of rice bran (normally retained on germinated brown rice products) comprises sterols, γ-oryzanol, tocopherol, tocotrrienols and phenolic compounds that prevent Diabetic complication, exhibit antioxidative activity, and

cholesterol- lowering effect, antimutagenic and anticancer effect that plays an important role in maintaining health [9]. Besides containing other useful component, it has been shown in a study conducted in Sierra Leone showed that continuous intake of GBR products over a period of time can provide a useful approach in the management of blood glucose levels in Diabetes Mellitus patients [10]. GBR may also help to reduce the cost of diabetes management and care.

The aim of the study is to investigate the effect of parboiled germinated brown rice on the blood glucose level and general health of patients suffering from Type II Diabetes Mellitus.

The objectives of the study are:

i. To compare the effect of Parboiled Germinated Brown Rice (PGBR) and normal Parboiled Brown Rice (PBR) on the blood-glucose levels and blood pressure of selected diabetics in the city of Bo.
ii. To determine the effect of Parboiled Germinated Brown Rice (PGBR) on the general wellbeing of type II Diabetics in the city of Bo.
iii. To assess the acceptability of parboiled rice on selected diabetes patient in the city of Bo and examined the feasibility of introducing parboiled germinated brown rice into their diets.

Diabetes Management

Diabetes care, similar to other chronic illnesses, has been focusing on the need to shift the traditional relationship between patients and healthcare professionals. As a growing burden of Diabetes results in significant morbidity and mortality, Diabetes care has been moved from provider-centred to patient-centred, such as from compliance/adherence to self-management [11]. To improve self-management, empowerment is adopted as the major concept of health care [12]. The chronic care model has been widely applied in health care organizations as a guide to transform practice in collaborative quality improvement programs that have addressed concerns to Diabetes [13]. Based on this concept, numbers of studies have shown positive impacts on metabolic control while using innovated Diabetes self-management programmes, but no study confirms that the strategy can be effective enough to sustain the necessary healthy living life changes that Diabetes requires [14]. Thus, apart from facilitating the chronic care model, to incorporate principles of behaviour change into all aspects of Diabetes care and link with community resources is to be taken into account while providing services [15]. However, to apply the principles of behavioural change is not common knowledge known among health care professionals, and as a result, they need to be trained properly. To achieve optimal treatment outcome, Type II Diabetes in particular requires patients to be adapted to the often-complex lifestyle changes and medical regimens Diabetes Mellitus; and by doing so they have to develop their own repertoires of self-management skills [7] because, in reality, immediate help from the health professionals is not enough. However, because the patients' health beliefs are unlike those of the doctors and nurses, this may prevent them from taking health-related advice, particularly when self-management is a greater burden than having asymptomatic disease. Thus, having a better understanding of patient perceptions by health professionals may improve the therapeutic agreement. It is essential to understand what the patients experience while integrating Diabetes in daily lives, as well as their thoughts and decision-making in the context of living with Diabetes while making efforts to improve Diabetes care.

The skills needed to be known by the patients with diabetes are identified as diet, exercise, self-monitoring of blood glucose, foot care, travelling and sick-day management, and taking medicine; they are the very ones responsible for carrying out day-to-day self-care activities [12]. After being diagnosed, Diabetic patients are expected to follow the prescribed therapeutic regimen, in which a change of lifestyle is considered the most difficult goal to achieve [16].

Glycaemic Index and Diabetes

The Glycaemic index (GI) is a concept introduced by Jenkins DJ, et al. [17] to classify foods based on their immediate effect on blood glucose levels. GI is defined as a measure of the blood-glucose-raising ability of the available carbohydrate in foods [17]. It is expressed as a percentage of the incremental area under the Glycaemic response curve (AUC) elicited by a portion of food containing 50g available carbohydrate in comparison with the AUC elicited by 50 g glucose in the same subject. Glycaemic index is a system of classifying carbohydrate containing foods according to Glycaemic response [18]. The principle is that the slower the rate of carbohydrate absorption, the lower the rise of blood glucose level and the lower the GI value [19]. A GI value of ≥70 is considered high, a GI value 56-69 inclusive is medium and a GI value ≤55 is low, where glucose = 100 ([20].

In recent years, consumer interest in GI has grown resulting in several retailers in the UK and Europe marketing low-GI foods. Food processors also have shown an increasing interest in developing and producing low-GI foods. As a first step it is important to identify the factors that influence and impact on the GI of foods [21]. There are several factors that may alter the GI of a food including the particle size, food structure, ripeness, ratio of amylose and amylopectin, starch structure, level of food processing, cooking technique and the presence of other macronutrients such as fat and protein [21]. A very simple example is the ability to lower the GI of white bread, which is normally considered to be a high-GI food, by decreasing its loaf volume [22]. The use of high-temperature and high-pressure extrusion technology used in food processing over the past five decades has increased the degree of starch gelatinization, resulting in easier accessibility of starch to enzymes thereby leading to faster digestion and high GI of starchy foods [23]. Consequently, there is considerable variation in the GI of the same food manufactured in different countries. Several studies have shown that the addition of fat and protein to a carbohydrate food can significantly reduce the Glycaemic response [24]. It has been suggested that fat lowers the postprandial glucose response by increasing the viscosity of the intestinal contents and delaying

the rate of gastric emptying; however other mechanisms may also be involved [25]. The addition of protein to a carbohydrate food increases the amount of insulin secreted, causing the blood glucose levels to be affected. Laville M, et al. [25] also suggested that protein might form a protective network around the carbohydrate molecule and prevent the action of glycolytic enzymes.

Glycaemic Indices of Some Rice Varieties

Rice constituting the basic food for large number of human beings, substituting two-thirds of the world population [26]. Starch is the storage polysaccharide of cereal grains, and comprise generally between 60 and 75% of the weight of the grains [27]. Starch is mainly found in the endosperm, in the form of semicrystalline granules embedded in a continuous protein matrix [28]. Starch digestibility can be affected by several factors including the composition and physical form of the starch, protein-starch interactions, the physical form of the food, the integrity of the containing cells, and presence of anti-nutritional factors. Food processing usually involves moisture, heat and mechanical action which permit gelatinization to occur. In general, when the processing leads to full gelatinization, the starch digestibility is enhanced. Based on the amylose content, rice can be divided into four groups, i.e. glutinous rice (amylose content < 10%), low amylose rice (amylose content 10-20%), medium amylose rice (amylose content 20-25%), and high amylase rice (amylose content > 25%) [29]. Rice varieties with slower digesting starches have health benefits attributed to, prevention and treatment of diseases such as diabetes, insulin resistance, obesity, cardiovascular disease, and some types of cancer [16].

Glycemic index (GI) is the level of foods according to their effect on blood glucose level. Foods that raise blood sugar content quickly have high GI values. Conversely, foods that raise blood sugar content slowly have low GI values. The GI values of foods are grouped into low GI (< 55), medium (55-70), and high (>70) [20]. The GI value is a very unique nature of food stuffs; it is influenced by the type of food materials, characteristics (composition and biochemical properties) of materials, processing methods, and cannot be predicted only based on one character of the materials. Each component of the food materials contributes to and gives a synergistic effect to characteristics of the materials that result in a certain Glycaemic response [20].

The GI concept is the development of fibre hypothesis which states that consumption of fibre will reduce the rate of input of nutrients from the intestine [20]. Fibres play important roles in maintaining health of individuals. Therefore, dietary fibre is one component of functional foods which today receives widespread attention. Dietary fibre is found in the form of a complex carbohydrate found in many plant cell walls [30]. Dietary fibre cannot be digested and absorbed by the human digestive tract, but it has a function that is essential for health maintenance, prevention of various diseases, and as an important component in nutrition therapy. This component consists of polysaccharides that cannot be digested, such as cellulose, hemicelluloses, oligosaccharides, pectin, gums, and waxes [30].

Dietary fibre affects glucose assimilation and reduces blood cholesterol. Certain plant fibres inhibit the absorption of carbohydrates and reduce blood sugar levels 2 hours after meals (postprandial). Increasing dietary fibre in the diet associated with a reduction of insulin resistance. Dietary fibres derived from cereals, beans, and vegetables are very beneficial for diabetic patients [30]. According to Sahoo U, et al. [31], rice with lower amylose content could have reduced starch digestibility due to crystallized resistant starch synthesized by linearized amylopectin slowly absorbed carbohydrates will produce a low peak of blood glucose levels and have a potential in controlling digestibility of rice starch, which is influenced by the composition of amylose and amylopectin. Starch content and composition of amylose and amylopectin affect digestibility of the rice starch in cooked rice. Most scientists believe that amylose is digested more slowly than amylopectin [30], because amylose is a polymer of simple sugars with a straight and unbranched chain. This straight-chain amylose develops a solid bond that is not easily gelatinized. Therefore, it is more difficult to digest amylose than the amylopectin, which is a branched and open structured simple sugar polymer. Based on these characteristics, foods that contain high amylose have higher hypoglycaemic activity than those having high amylopectin.

Based on the mechanism of enzymatic hydrolysis, amylases are one of the groups of enzymes that hydrolyse starch during digestion of starch-containing foods. In the gastrointestinal tract, this is enhanced by the action of alpha-amylase alpha-glucosidases [30]. The alpha-amylases randomly hydrolyse alpha-1, 4 glucosidal bonds, generating maltose and short linear oligosaccharides. Beta-amylase and amyloglucosidase have exo-amylase activity, attacking the terminal glucose residues to yield maltose and glucose, respectively. Other enzymes such as pullulanases are classified as debranching enzymes which may also be used in some starch digestibility systems [30].

Nutritional Value of Brown Rice as Compared to White Rice

Brown rice and white rice have similar amounts of calories and carbohydrates. The main differences between the two forms of rice lie in processing and nutritional content. When only the outermost layer of a grain of rice (the husk) is removed, brown rice is produced. To produce white rice, the next layers underneath the husk (the bran layer and the germ) are removed, leaving mostly the starchy endosperm. By removing the bran and germ portions of brown rice during processing, subsequently lead to disruption of the physical and botanical structure of rice grains resulting to loss of fibre, vitamins, magnesium and other minerals, lignans, phytoestrogens, and phytic acid, many of which may be protective factors for diabetes risk. When the bran layer is removed to make white rice, the oil in the bran is also removed. Rice bran oil may help lower LDL cholesterol.

Germinated Brown Rice (GBR)

Germinated brown rice is unpolished brown rice, used primarily

as a food grain that has been allowed to germinate in order to alter the flavour and also to increase levels of nutrients such as γ-aminobutyric acid (GABA). Germinated brown rice has a softer texture than brown rice and a pleasant fragrance yet retains the health benefits of brown rice.

Germination is the process of subjecting viable rice grains (paddy) to germination conditions which yield approximately 0.5mm to 1mm long sprout from the brown rice grain; at this stage nutritional accumulation in the grains is at its maximal. The process involve by steeping the paddy in water at room temperature for about 8 to 12 hours; within this period the water should be change every 2 hours to prevent fermentation and bad odour and also to maintain water temperature, drain and germinate for twenty- four (24) to seven-two (72) hours in a dark, semi-airtight environment at a temperature of 37 to 40°C and then dried in to a moisture content of about 12%. GBR has been shown to contain enhanced levels of some bioactive compounds and reduced levels of some anti – nutritional factors. Watchararparpaiboon W, et al., [32] indicate that the volume of nutrient contained in GBR relative to milled rice are ten times for GABA nearly four times for dietary fibre, vitamin E, niacin and lysine and about three times for vitamin B_1 and B_6 and magnesium. During the germination process, saccharification softens the endosperm and dormant enzymes are activated which increase the number of digestible vitamins, minerals and amino acids. This causes significant changes in the nutritional and physiological properties as well as textural characteristics. Suresh A et al., [30], Upasana Sahoo U, et al., [31], Watchararparpaiboon W, et al., [32] reported that the consumption of brown rice is better compared to polished rice. Brown rice is rich in fibre, iron, vitamin and minerals in it outer brown layer. Further, the germination of brown rice is necessary for enhancing require for a good health. The change in consumption of staple food from polished rice can maintain and promote the healthy life and improve the quality of life [32].

Advantages of GBR as a Food

Various types of analysis on GBR conducted in Japan indicated that germination process resulted to drastic change of nutrient in brown rice. Kayahara H, et al., [33] have shown that, not only the existing nutrients are increased but new components are also released from the inner change due to germination. The nutrients which have been shown increase significantly include GABA, lysine, dietary fibre, magnesium, vitamin E, vitamin B_1, B_3 and B_6 [33]. The other nutrients that increased in GBR were inositols, ferulic acid, phytic acid, tocotrienols, potassium, zinc, γ-oryzanol, and prolylendopeptidase inhibitor [7]. In particular, the amount of GABA in GBR was noticed to be ten times more as compared to polished rice and two times more than that of brown rice. They also found that GBR contains fewer calories and sugar than that in milled rice. Free amino acid (FAA) accumulation occurs during germination process of rice grain. The production of GBR, also known as GABA is recent application that takes advantage of the FAA accumulation ability of germinating rice grains [34].

Advantages of GBR as a Functional Food

Petil & Khan [7] concluded that continuous intake of GBR is good for accelerating metabolism of brain, preventing headache, relieving constipation, preventing cancer of the colon, regulating blood sugar level, preventing heart diseases, lowering blood pressure as well as preventing Alzheimer's diseases. New research from the University of Missouri School of Medicine suggests intensive lifestyle interventions are an effective way of treating and improving liver disease [35]. More recently found out that GBR may be effective for suppressing liver damage [35]. Other studies have also shown that GBR suppress body weight gain and lipid accumulation in the liver [9].

Properties of GBR

Jiamyangyuen, & Ooraikul [36], reported that effect of germination on cooking and textural properties of cooked rice were more pronounced when rice was soaked and germinated for longer period. They reported that germinated rice required less cooking time and water absorbed by kernel during germination results in size expansion. From the sensory evaluation, they have shown that the cooked germinated rice is sweeter, softer, swelled and cohesive than cooked regular brown rice. Kayahara H, et al., [33] observed that GBR have a softer texture than normal brown rice due to the reaction between phytic acid and minerals during the birth of the sprout which indicates that it can be easily cooked and is easier to digest.

Role of Germinated Brown Rice in Diabetes Prevention

GBR contains natural source (proanthocynin), which helps in the prevention of diabetes, cancer and some forms of cardiovascular diseases.

A study publish in the Archives of Internal Medicine, shows that replacing about 50 grams of white rice (equal to about one third of a daily serving) with the same amount of brown rice lowers the risk of type II diabetes by sixteen percent [37]. The study also reveals that five or more servings of white rice per week were associated with an increased risk of Type II Diabetes. Blood concentrations of fasting blood glucose, frutosamine, serum total cholesterol and triacyglycerol levels have been shown to favourable improve on a pre-germinated brown rice diet, suggesting that diets including pre-germinated brown rice may be useful to control blood glucose levels in Type II Diabetes [37].

Therefore, a self-help strategy of merely eating more germinated brown rice and other whole grains along with adequate and regular exercise, and appropriate weight management could potentially prevent and even reverse cases of Type II Diabetes.

Parboiled Germinated Brown Rice

Parboiled of paddy is a hydro-thermal process or treatment that results in the gelatinization of starch within the rice grain. It changes the starch from crystalline to an amorphous one and as a result of this transformation, the orderly polyhedral structure of the compound of starch granules changes into a coherent mass

acquiring a greater strength to resist milling forces and thereby less breakage and lesser loss of nutrient. The process of parboiling consists of pre-soaking of paddy in water until saturation, with subsequent steaming followed by drying.

The penetration of water into the rice kernel is important as this process results in less breaking during milling, thus increasing yield and milling efficiency [38]. Soaking of paddy forms an important operation since the duration of soaking directly affects parboiling. Theoretically, soaking of paddy can be done at, or below, its gelatinization temperature. The lower the temperature used, the slower is the process of soaking. The higher the temperature of the stem and the larger the steaming time, the harder the rice and darker is the colour. Keeping steam paddy in a heap is equivalent to prolonged steaming and induces the same effect. Shade or lower temperature drying gives an excellent milling quality but takes longer time. Rapid drying in the sun or with hot air causes higher breakage during milling.

Parboiled germinated brown rice (PGBR) is GBR that has undergone parboiling process. It is practiced in many countries, but they consume lot of polished rice. Some of these countries the rice they utilised, 50% of it is polished. But PGBR has lots of nutritional benefits it contains bran layers and embryo, where a variety of nutritional and biofunctional components, such as dietary fibers, γ-oryzanol, vitamins, and minerals, exist. However, BR is consumed less than white rice because it has an inferior eating texture when cooked [39]. Probably to accelerate ageing of freshly harvested rice [40]. Parboiling is also a "salvage" process used to upgrade chalky and wet fermented discoloured paddy, which otherwise would produce unacceptably low milling recovery [41]. Therefore, combining the processes of both germinated and parboiling yields rice with improve nutritional value, milling yield and shelf life. It may also help to sterilize the germinated rice. Buggenhout J, et al., [42], suggested that parboiling fills the void spaces and cements the cracks inside the endosperm, making the grain harder and minimizing internal fissuring and thereby breakage during milling.

Potential Health Benefits of Parboiled Germinated Brown Rice in Diabetes Prevention

Parboiled Germinated brown rice (PGBR) is considered whole food because only the outermost layer i.e. the hull of the rice kernel is removed which causes least damage to its nutritional value. The continuous intake of PGBR is good for preventing headaches, relieving constipation, preventing cancer of the colon, regulating blood sugar level and preventing heart disease. The intake of GABA – a compound found in GBR, suppresses blood pressure and improves sleeplessness and autonomic disorder observed during menopausal or presenile period [43]. GBR helps in prevention Alzheimer's disease due to its increased GABA content. For patient with hyperglycaemia, the intake of GBR is effective for the control of post-prandial blood glucose concentration with increasing insulin secretion [44].

In addition to the physical changes conferring favourable organoleptic attributes, GBR has been shown to contain enhanced levels of some bioactive components and reduced levels of some anti-nutritional factors. For instance, GBR is well known for its enhanced levels of ɤ-amino butyric acid (GABA), γ-oryzanol and α-tocopherol. These bioactive compounds have been show to bear epidemiological links to some of the leading killer disease in Sierra Leone, including Diabetes and High Blood Pressure. For instance, γ-oryzanol is a strong antioxidant (four times stronger than that of α-tocopherol) which lowers blood cholesterol, inhibits thyroid stimulating hormone TSH) level in hypothyriodic patient, reduces menopausal symptoms, aids muscle development and suppresses cancer [45]. The other name for GBR is 'GABA rice'. This is because; this non-protein amino acid (which is an important neurotransmitter in humans) happens to be the most rapidly increasing free amino acid in germinated brown rice. GABA is believed to have important effect on Hypertension, Brain Metabolism and Presenile Derangement. GBR may however be considered as one of the cheapest sources of this important compound. Other functional component in GBR have a wider range of benefits, ranging from fat metabolism, protection of heart, slowing down human ageing, relieving constipation and possibility of preventing Alzheimer's disease.

It is concluded that germinated brown rice has potential to become innovative rice by preserving all nutrient in the rice grain for human consumption in order to create the highest value from rice. Germinated brown rice contains nutrients and has numerous health benefits as given below:

Nutrients

Vitamin E: Higher levels of vitamin E in GBR compared to non-germinated brown rice.
Fiber: GBR has more dietary fiber than non-germinated brown rice.
Protein: GBR has more protein than non-germinated brown rice.
Healthy fats: GBR has more healthy fats than non-germinated brown rice.
Antioxidants: GBR has higher levels of antioxidants than non-germinated brown rice.
GABA: GBR has more gamma aminobutyric acid (GABA) than non-germinated brown rice.
Bioactive components: GBR contains ferulic acid, γ-oryzanol, and other bioactive components.

Health Benefits

Blood sugar: GBR has a lower glycemic index, which may help with blood sugar management.
Chronic disease risk: GBR may reduce the risk of chronic diseases like cancer, diabetes, and cardiovascular disease.
Digestion: GBR is good for digestion and absorption.
Weight management: GBR may help with weight management.
Immunity: GBR may boost immunity.
Sleep: GBR may promote sound sleep.

GBR is also easier to cook and has a better texture than non-germinated brown rice.

To ensure the sprouting process doesn't spoil the rice, it should be done under controlled temperature and humidity conditions.

Materials and Methods

Study Location

The preparation (germination and parboiling treatment) of the rice samples for this study was carried out at the Agricultural Engineering Department in the School of Technology, Njala Campus. Clinical trials were conducted in the Bo Government Hospital in the city of Bo, Southern Sierra Leone after obtaining ethical clearance from the Ministry of Health and Sanitation.

Materials

The rice samples used in this study were obtained from field personnel of the Ministry of Agriculture Forestry and Food Security Stationed in the Bo District Sierra Leone.

Data Collection Procedure

Three sets of data were collected in this study. The data for the clinical trials were obtained from twenty (20) randomly selected diabetes patients (as subject) age group thirty-five (35) to sixty-five (65) years, over a period of four months to determine the effect of PGBR on their blood glucose levels and general well-being. The data for acceptability of the rice treatment were obtained from the same subjects through subjective evaluation conducted over the course of the trial and recorded in special data entry sheet, administered to individual patients on a weekly basis over the course of the trial.

Sample Preparation

Fertile grains of improved rice variety, Nerica 19, produced in Sierra Leone were subjected to germination and parboiling treatment to produce parboiled germinated brown rice (PGBR). Germination treatment involved thorough washing of paddy, steeping in water at room temperature for at least twelve hours during which water was changed at three to four hours interval to prevent microbial contamination which could lead to the development of odours and fermentation. The hydrated grains are then subjected to germination in a dark airtight chamber for up to 48 hours before the process is terminated by exposing the germinating grains to parboiling conditions in an improved steam per boiler for about 45 minutes or until the hull begins to split open. The parboiled grains are then dried in the open air under ambient conditions to moisture content of about 12%. All the rice samples were milled in the Department of Agricultural Engineering, (Njala University), using a two-stage SB-10 rice milling machine.

Clinical Trials

Study Design and Ethical Issues

The study was a double blind parallel-arm clinical trial in which there was a control group and a treatment group which was conducted in the Bo Government Hospital, in Bo, Sierra Leone, under the supervision of the Medical team of the Health Centre. The protocols of this study were approved by the Ethical Committee of the Ministry of Health and Sanitation. Some of the ethical issues involved, conformity with clinical regulations, subject's information and knowledge, subject's informed consent prior to participation, voluntary participation and freedom to withdraw from studies, use of placebo treatment group, confinement of subject's personal information and random selection of subjects to avoid bias.

Patient Orientation and Informed Consent

The Subjects were briefed on the significance of the study, the potential health-related benefit of PGBR in the management of type II diabetes and associated diseases, and the importance of compliance over the four-month period of the clinical trial. They were encouraged to use the rice supplied to them as their main diet and they should avoid eating other rice till the end of the clinical trial. Informed consent was obtained from each subject. All subjects supplied baseline information on their diets, medications, lifestyle, and general wellbeing; their fasting blood glucose, blood pressure, weight, and height were also measured. The fasting blood glucose was calculated in mmol/L, blood pressure (Systolic and Diastolic) were measured in mmHg and body mass index (weight/height) were calculated in kg/m^2.

Randomization and Treatment Assignment

The patients were asked to ballot and were randomly assigned to two groups of ten (10) participants each. One group was placed on Parboiled Germinated Brown Rice and (was called the treatment group) and the other group was placed on Ordinary Parboiled Brown Rice (placebo) and was called the controlled group. It was assumed that all of them had taken up a regular diet of Ordinary Parboiled Rice. To ensure complete blinding, all weekly rice samples were coded uniquely and neither the subjects nor the clinical coordinator (physician) were aware of the group assignments.

Administration of Treatments

Every week, each subject received a 3kg package of rice on a free of charge basis. The subjects/participants were interviewed about their weekly diet, general wellbeing, perception and acceptability of the treatment given to them. Their blood glucose, blood pressure and body mass index were also recorded on a weekly basis. After two months, subjects were encouraged to go back to their normal diets and activities for a period of two weeks. During this period their fasting blood glucose, blood pressure and body mass indices were monitored. Cross over treatment was applied by switching over subjects who received PGBR to PBR vice versa.

Data Analysis

Data obtained from the study were analysed in a spread sheet using Microsoft Excel 2007 with Real Stats add-in. Analysis involved the determination and comparison of group means. Carry over effect was determined by the comparison of treatment effects before and after crossing over. However due to significant carryover effect detected the data was analysed as a simple parallel design, instead

of a cross over design, to test the relative contributions of PGBR and GBR with respect to the relevant health indicators.

Results and Discussions

Results on the Characteristics of subjects Eating habits

The outcome of baseline interviews conducted prior to commencement of the study indicates that all participants eat parboiled rice as a normal diet. Although some had reservations against certain sensory features of they had accepted a regular diet of parboiled rice since they were diagnosed of diabetes. Many of them consume this with various combinations of unripe banana and plantain, bulgur, millet, fruits and green leafy vegetables some time used as an accompaniment to the parboiled rice or bulgur wheat.

Table 1: The general attitude of participants towards rice products received over a period of nine weeks.

Product Received	Subject Impressions									
	Wk 0	Wk 1	Wk 2	Wk 3	Wk 4	Wk 5	Wk 6	Wk 7	Wk 8	Wk 9
PGBR	+	+	+	+	+	+	+	+	+	+
PGBR	+	+	+	+	+	+	+	+	+	+
PGBR	+	+	+	+	+	+	+	+	+	+
PGBR	+	+	+	+	+	+	+	+	+	+
PGBR	+	+	+	+	+	+	+	+	+	+
PGBR	+	+	+	+	+	+	+	+	+	+
PGBR	+	+	+	+	+	+	+	+	+	+
PGBR	+	+	+	+	+	+	+	+	+	+
PGBR	+	+	+	+	+	+	+	+	+	+
PGBR	+	+	+	+	+	+	+	+	0	+
PBR	+	+	+	+	+	+	+	+	+	+
PBR	+	+	+	+	+	+	+	+	+	+
PBR	+	+	+	+	+	+	+	+	0	+
PBR	+	+	+	+	+	+	+	+	+	+
PBR	+	+	+	+	+	+	+	+	+	+
PBR	+	+	+	+	+	+	+	+	0	+
PBR	+	+	+	+	+	+	+	0	+	+
PBR	+	+	+	+	+	+	+	0	+	+
PBR	+	+	+	+	+	+	+	+	+	+
PBR	+	+	+	+	+	+	+	+	+	+

" + " = like, " – " = dislike, " 0 " = absent

Impression of Parboiled Rice

The participants' impression about parboiled rice is summarized in Table 1. The data does not show any evidence of aversion to parboiled rice products received by participants throughout the study. This was an indication of its suitability for the study. In fact, some participants noted that they find the parboiled rice products received during the trial to be of a superior quality compared to that available in the local market.

Preference for Rice Products Based on Specific Criteria

The relative preference of participants for PGBR and GBR was determined on the basis of general appearance, taste / flavour, texture / mouth feel and smell / aroma over the course of the study. The results (Figure 1) show that the sensory qualities of both products were acceptable (or liked) to almost all participants (97.4% to 100.0%). There was no significant difference between preference for PGBR and PBR, suggesting the absence of bias.

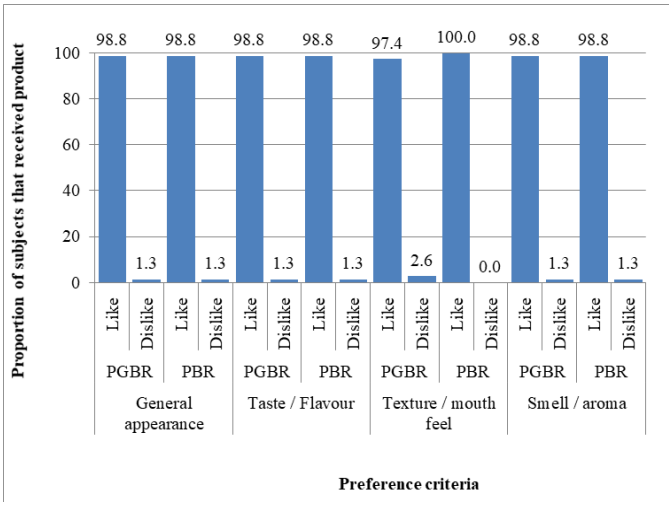

Figure 1: Participants preference for rice products received over a period of eight weeks.

Subject Monitoring

Blood glucose

The blood glucose of subjects assigned to PGBR and GBR diets were monitored over a period of eight weeks. Figure 2 shows the blood glucose data for the two diet groups over the trial period. Whereas the PGBR group started from an average of 10.8 mmol/lit the PBR group entered the study with an average blood sugar of 6.6 mmol/lit. The result shows a decline in the average blood glucose value of the PGBR group from the baseline value of 10.8 mmol/lit to 7.4 mmol/lit within the first three weeks and was maintained between 8.0 and 6.9 mmol/lit (consistently below the baseline) throughout the study. However, the PBR group fluctuated between an average of 5.4 mmol/lit and 7.8 mmol/lit. This result suggests that PGBR has more positive effect on the reduction of blood glucose than PBR. Both treatment groups showed downward trend in blood glucose readings of participants but this trend was more prominent for the PGBR diet group.

Blood pressure

Blood pressure readings of participating subjects were monitored over the course of the trial. Figure 3 shows the diastolic and systolic blood pressure for subjects assigned to PGBR and PBR diet groups over a period of eight weeks. The average systolic pressure of the PGBR diet group progressed rapidly from 100 mmHg to 86 mmHg

in the first week and continued to progress slowly downward to 81 mmHg by the 8th week before it started to fluctuate but stayed below the baseline over the remaining weeks. A similar pattern was also observed for the PBR group up to the 7th week before it started to fluctuate over the subsequent weeks. In the case of diastolic blood pressure, the PGBR group entered the trial with a baseline of 148 mmHg, which declined to 127 mmHg over a course of four weeks before it started fluctuating with a minimum of 120 mmHg and a maximum of 137 mmHg (significantly less than the baseline value) over the rest of the trial. However, the PBR group entered the trial with an average diastolic blood pressure of 141 mmHg, which fluctuated throughout the study with a minimum of 124 mmHg and a maximum of 144 mmHg (greater than the baseline value). Data suggest greater improvement in the PGBR group with respect to both systolic and diastolic blood pressure.

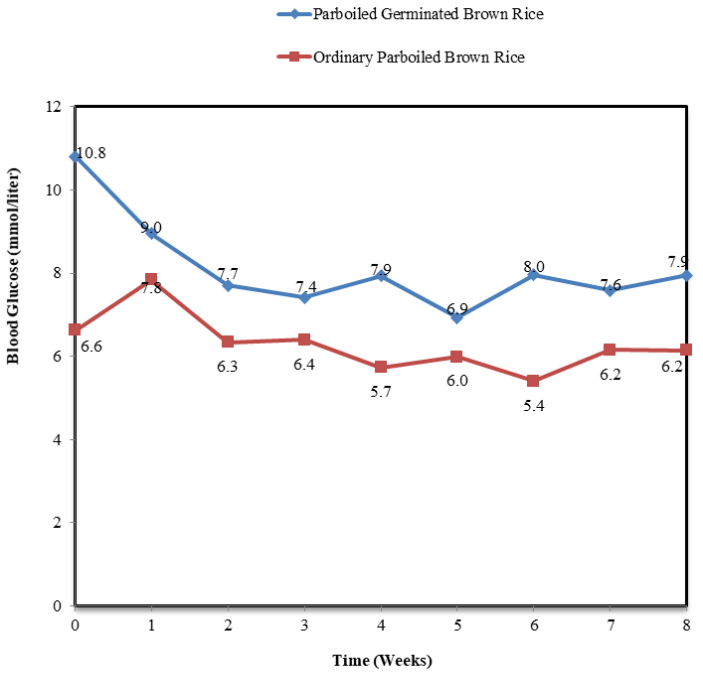

Figure 2: Average fasting blood glucose for PGBR and PBR diet groups monitored over a period of 8 weeks.

Relative differences in blood monitoring data

In order to clarify the overall effect of the two rice treatments the cumulative percent deviations from the baseline was determined for all weeks and averaged for the trial period. Figure 4 shows the comparative change in blood pressure and serum glucose for the two diet groups (PGBR and PBR). The data shows that both rice products appeared to result in improvements (reductions) in the blood pressure and blood glucose of subjects. However, whereas PBR resulted in net 2.9%, 3.6% and 5.7%, PGBR resulted in 12.7%, 13.6% and 27.8% reductions in systolic blood pressure, diastolic blood pressure and blood glucose respectively. Thus, the data shows that PGBR appeared to be about 4 and 5 times more effective in improving blood pressure and blood glucose than ordinary PBR.

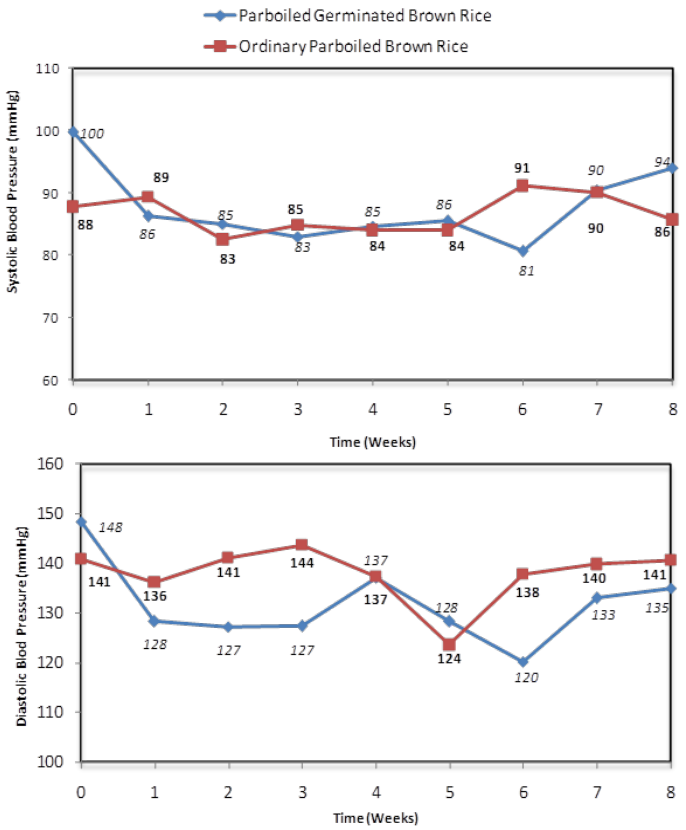

Figure 3: Average systolic (top panel) and diastolic blood pressure for PGBR and PBR diet groups monitored over a period of 8 weeks.

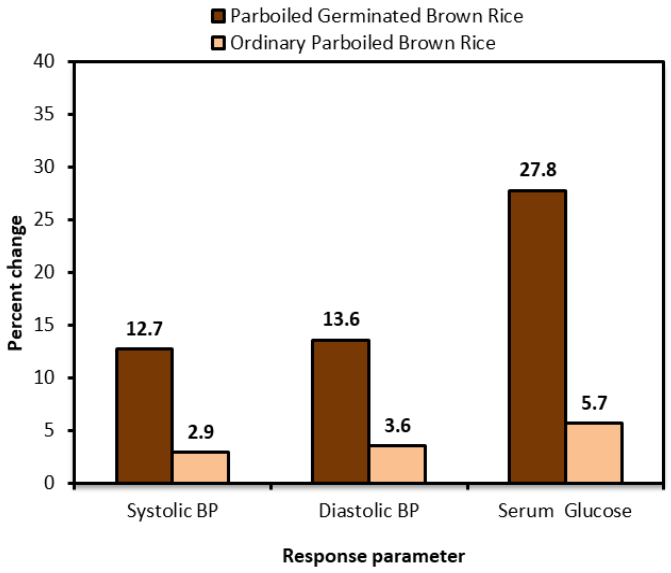

Figure 4: Comparative change in subjects' blood glucose and pressure after continuous intake of parboiled germinated brown rice (PGBR) and normal parboiled brown rice (PBR) over a period of eight weeks.

Subjects' Health and Well Being

Body Mass Index (BMI)

Figure 5 shows the effect of continuous consumption of PGBR and PBR on the body mass index (BMI) of participating subjects. The

index BMI is an anthropometric measure that expresses the mass of subjects as a ratio of the square of their height. The calculated value is then compared to that of a reference population to draw an inference. The results from the BMI data shows that participants on PGBR showed a downward trend in their BMI values from a baseline of 29.2 down to 27.0 during the first six weeks, before it started fluctuating significantly. Progressive reduction in BMI implies apparent weight loss for the PGBR diet group over the course of the study. On the other hand, the BMI values of subjects on PBR appeared to have a slight upward trend from 29.2 to 30.2, indicating an apparent weight gain over the course of the trial.

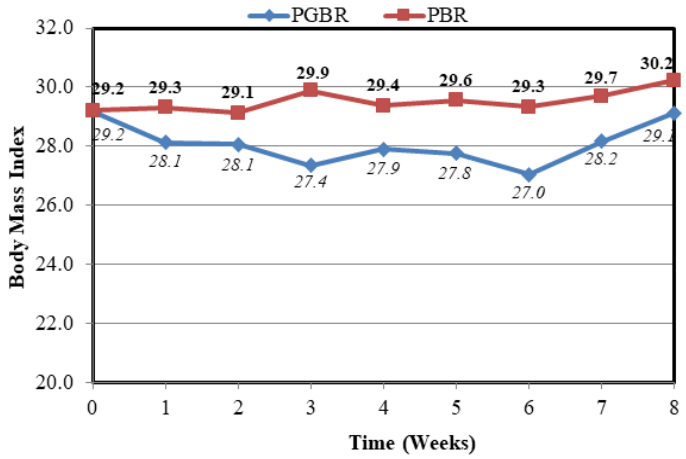

Figure 5: The body mass index (BMI) of diabetic subjects after continuous intake of parboiled germinated brown rice (PGBR) and normal parboiled brown rice (PBR) over a period of eight weeks

Bowel movements

To determine whether the rice diets induced negative changes in the bowel movement of participants, their weekly responses to questions relating to their bowel movement over the course of the week were solicited and tallied. Figure 6 shows the frequency distribution of four states of bowel movement (improvement, normal, constipation and loose bowel movements) reported by the PGBR and PBR diet groups. The data shows sixty-four cases of normal or improved bowel movement in both diet groups with twelve (PGBR) and nine (PBR) cases of constipation, and two (PGBR) and three (PBR) cases of loose bowel movement reported. Statistical comparison of the distribution in the two groups using Chi-square test shows that the two groups were similar in terms of the responses compared.

General health and well being

Figure 7 shows frequency distribution of participants' responses to questions relating to their general feelings experienced during weekly interviews conducted over the course of the trial. The result shows that almost all the participants were responding favorably to both diets, with only one (PBR) and three (PGBR) cases of negative change in feeling. The majority (PGBR = 62 and PBR = 61) reported improvements in the way they felt during the week. Statistical comparison of the distribution in the two groups using Chi-square test shows that both groups had similar responses.

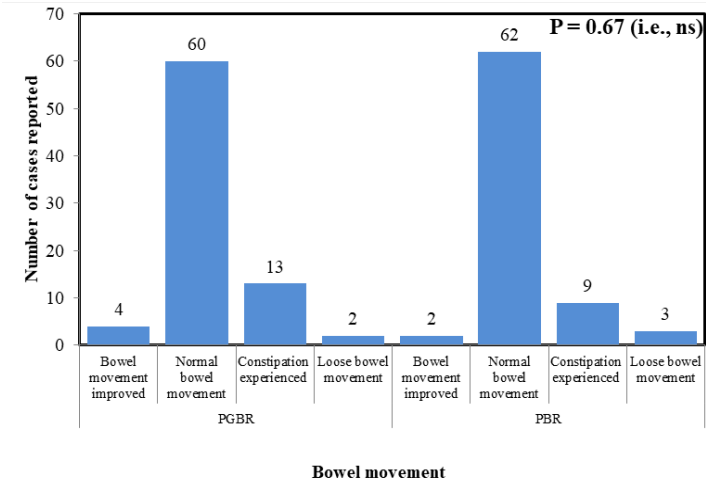

Figure 6: Frequency distribution of the responses given by participants in the PGBR (left) and PBR (right) groups with respect to bowel movements experienced over the course of the trial.

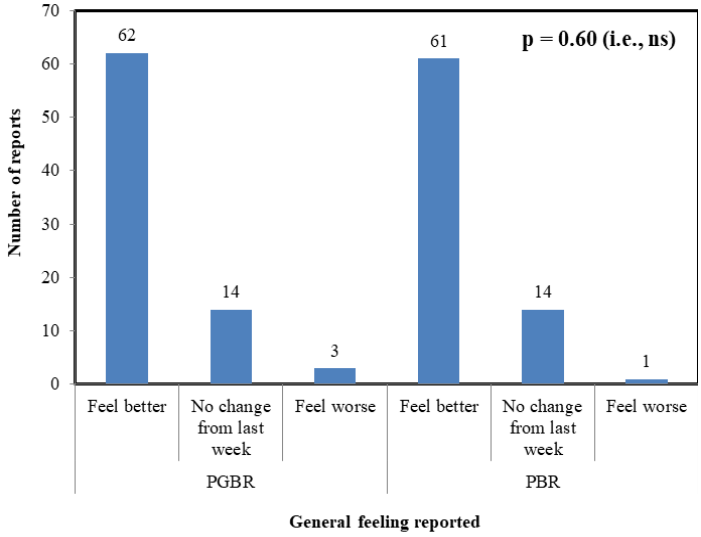

Figure 7: Frequency distribution of the responses given by participants in the PGBR (left) and PBR (right) groups with respect to general feelings experienced over the course of the trial.

Carryover effect

After the crossover period, the analysis of carryover effect was determined and found to be only slightly significant. Thus, the data was ignored since it would not provide additional information other than to suggest that the effect of the products used tend to persist long after the treatment is stopped.

Discussion

A four-month clinical trial was conducted in order to compare the effect and acceptability of parboiled germinated brown rice and normal parboiled brown rice on the blood glucose level and general wellbeing of selected diabetes patients in a public hospital. The general result obtained from the monitoring data shows

that parboiled germinated brown rice has more positive effect in controlling blood glucose, blood pressure and body weight as compared to ordinary parboiled brown rice. The health beneficial effects of PGBR observed in this study must have been result from several mechanisms which have being proved by other studies on parboiled and germinated rice products. In their natural form, whole rice grains which are normally rich in fibre are also known to have the beneficial effects of lowering fasting insulin level and decreasing the risk of cardiac disease in diabetics and obese adult [46].

Studies involving the use of germinated brown rice have shown successful reduction in blood glucose in type II diabetic subjects [46-48]. Brown rice is rich in fibre, iron, vitamin and minerals in it outer brown layer. The knowledge of the health-related benefits of functional food filters down across the rice eating world. Pre-germinated brown rice as a functional food has recently being considered by many studies as better option in the management of type II diabetes. Further, subjecting brown rice to germination treatment results in the breakdown of higher molecular weight polymers, leading to significant changes in the texture and flavor of brown rice thus, this alleviates the problem associated with the cooking of brown rice [33].

Evidence suggests that the mechanism for the antidiabetic effect of GBR is related to the production of bioactive compounds like γ-aminobutyric acid (GABA), γ-oryzanol, dietary fibre, phenolic, vitamins, acylated steryl *β*-glucoside, and minerals, which increase as a result of germination processing [49]. Fibre slows carbohydrate digestion and glucose absorption, thus, induce lower glycaemic response and therefore lower glycaemic index (GI). The principle is that the slower the rate of carbohydrate absorption, the lower the rise of blood glucose level and the lower the GI value [5]. Rice with lower GI has benefits attributed to prevent and treatment of diseases such as diabetes, insulin resistance, obesity, cardiovascular diseases and some form of cancer [50]. Ito Y, et al., 50 reported that GBR containing 50g available carbohydrate portion produced better glycaemic and insulin response than corresponding amounts of BR and WR.

Normal parboiled rice is known to reduce blood sugar since it has lower glycaemic index in human trial conducted in Bangladesh and the United States, respectively [51-53]. In a clinical study conducted, PGBR was shown to have lower glycaemic index as compared to PBR and BR [54]. This suggests that a combination of parboiling with germination processing could lead to additional health benefits. Findings from the present trial indicates that replacing PGBR with PBR in diabetic subjects will enhance better result in the patient general health and wellbeing. In terms of the relative acceptability of this product, the result shows that participants accept the product and responded very well compared to their baseline conditions. It is therefore logical to speculate that this effect of PGBR must have resulted from the bioactive compounds produce during germination which also increase it functional effects as well as the slow digestibility of parboiled rice grains. Thus, substituting PBR with PGBR would help to improve a number of health parameters that could be beneficial in the management of type II diabetes.

Conclusion

Type II diabetes has become a global public health problem because of its increasing rate across the world. Diet is an important parameter which needs to be considered in controlling and managing of type II diabetes. The study sought to test the efficacy of a food-based intervention in the management of type II diabetes. The overall results from this clinical study demonstrated a positive effect of PGBR on the blood glucose level, blood pressure and general wellbeing of diabetic human subjects as compared to PBR. These deduce that substituting PGBR with PBR would help to improve a number of health parameters that may be beneficial in the management of type II diabetes. The positive attitude of the participants in accepting the rice product given to them during the course of the study makes the feasibility of introducing this product to the general populace undoubtable. Thus, there are strong chances that the switch in the consumption patterns from polished rice to parboiled germinated brown rice could lead to many useful immediate gains in the health of an average Sierra Leonean.

References

1. Tabish SA. Is Diabetes Becoming the Biggest Epidemic of the Twenty-first Century. Int J Health Sci. 2007; 1: V-VIII.
2. Aston LM. Glycaemic index and metabolic disease risk. Proc Nutr Soc. 2006; 65: 125-134.
3. Shaw JE, Sicree RA, Zimmet PZ. Global Estimates of the Prevalence of Diabetes for 2010 and 2030. Diabetes Res Clin Pract. 2010; 87: 4-14.
4. Kamara IF, Tengbe SM, Bah AJ, et al. Prevalence of hypertension, diabetes mellitus, and their risk factors in an informal settlement in Freetown, Sierra Leone: a cross-sectional study. BMC Public Health. 2024; 24: 783.
5. Bouché C, Rizkalla SW, Luo J, et al. Five-week, low-glycemic index diet decreases total fat mass and improves plasma lipid profile in moderately overweight nondiabetic men. Diabetes Care. 2002; 25: 822-828.
6. Cheng Z, Qiao D, Zhao S, et al. Wholegrain rice: Updated understanding of starch digestibility and the regulation of glucose and lipid metabolism. Compr Rev Food Sci Food Saf. 2022; 21: 3244-3273.
7. Patil SB, Khan MK. Germinated brown rice as a value-added rice product: A review. J Food Sci Technol. 2011; 48: 661-667.
8. WHO (2024) World Diabetes Day/World Diabetes Day 2024. ttps://www.who.int/campaigns/world-diabetes-day/2024
9. Jabeen R, Jan N, Naseer B, et al. Development of Germinated-Brown-Rice-Based Novel Functional Beverage Enriched with γ-Aminobutyric Acid: Nutritional and Bio-Functional Characterization. Foods. 2024; 13: 1282.
10. Sundufu AJ, Bockarie CN, Jacobsen KH. The prevalence of type 2 diabetes in urban Bo, Sierra Leone, and in the 16

countries of the West Africa region. Diabetes Metab Res Rev. 2017; 33.

11. Lutfey KE, Wishner WJ. Beyond "compliance" is "adherence". Improving the prospect of diabetes care. Diabetes Care. 1999; 22: 635-639.
12. Anderson RM, Funnell MM. Patient empowerment: reflections on the challenge of fostering the adoption of a new paradigm. Patient Educ Couns. 2005; 57: 153-157.
13. Bodenheimer T. Primary Care-Will It Survive. New England J Med. 2006; 355: 861-864.
14. Norris SL, Engelgau MM, Narayan KM. Effectiveness of self-management training in type 2 diabetes: a systematic review of randomized controlled trials. Diabetes Care. 2001; 24: 561-587.
15. Glasgow RE, Fisher L, Skaff, et al. Problem Solving and Diabetes Self-Management: Investigation in a Large, Multiracial Sample. Diabetes Care. 2007; 30: 33-37.
16. Whittemore R. Strategies to Facilitate Lifestyle Change Associated with Diabetes Mellitus. J Nursing Scholarship. 2000; 32: 225-232.
17. Jenkins DJ, Wolever TM, Taylor RH, et al. Glycemic index of foods: a physiological basis for carbohydrate exchange. Am J Clin Nutr. 1981; 34: 362-366.
18. Al-Dhaheri AS, Henry J, Lightowler HJ, et al. Role of Body Composition in the Glycaemic Response to Foods Fed to Three Different Ethnic Groups: A Pilot Study. Annals of Nutr Metab. 2010; 56: 217-224.
19. Adedayo BC, Adebayo AA, Nwanna EE, et al. Effect of cooking on glycemic index, antioxidant activities, α-amylase, and α-glucosidase inhibitory properties of two rice varieties. Food Sci Nutr. 2018; 6: 2301-2307.
20. Brand-Miller J, Wolever TMS, Foster-Powell K, et al. The New Glucose Revolution: The Authoritative Guide to the Glycemic Index, Marlowe and Company, New York. 2003.
21. Gilbertson HR, Thorburn AW, Brand-Miller JC, et al. Effect of low-glycemic-index dietary advice on dietary quality and food choice in children with type 1 diabetes. Am J Clin Nutr. 2003; 77: 83-90.
22. Jiménez FEG, Luna HER, Avalos SR, et al. Development of low-glycemic white bread using Oxalis tuberosa dietary fiber as a functional ingredient for nutraceutical benefits. Applied Food Res. 2025; 5: 100649.
23. Moghaddam E, Vogt JA, Wolever TMS. The Effects of Fat and Protein on Glycemic Responses in Nondiabetic Humans Vary with Waist Circumference, Fasting Plasma Insulin, and Dietary Fiber Intake. J Nutr. 2006; 136: 2506-2511.
24. Patindol J, Newton J, Wang YJ. Functional Properties as Affected by Laboratory-Scale Parboiling of Rough Rice and Brown Rice. J Food Sci. 2008; 73: 370-377.
25. Laville M, Rigalleau V, Riou JP, et al. Respective role of plasma nonesterified fatty acid oxidation and total lipid oxidation in lipid-induced insulin resistance. Metabolism. 1995; 44: 639-644.
26. Zhou Z, Robards K, Helliwell S, et al. Composition and functional properties of rice. Inter J Food Sci Techn. 2002; 37: 849-868.
27. Nowak E, Khachatryan G, Wisła-Świder A. Structural changes of different starches illuminated with linearly polarised visible light. Food Chem. 2021; 344: 128693.
28. Rooney L, Pflugfelder R. Factors affecting starch digestibility with special emphasis on sorghum and corn. J Anim Sci. 1986; 63: 1607-1623.
29. Bienvenido O, Juliano BO. Improving Food Quality of Rice. Chapter 89, Book Editor: DR Buxton, R Shibles, RA Forsberg, BL Blad, KH Asay, GM Paulsen, RF Wilson.

i. https://doi.org/10.2135/1993.internationalcropscience.c107

30. Suresh A, Shobna, Salaria M, et al. Dietary fiber: an unmatched food component for sustainable health. Food and Agricultural Immunology. 2024; 35: 2384420.
31. Sahoo U, Biswal M, Nayak L, et al. Rice with lower amylose content could have reduced starch digestibility due to crystallized resistant starch synthesized by linearized amylopectin. J Sci Food Agric. 2024; 105: 3064-3072.
32. Watcharparparpaiboon W, Laohakunjit N, Kerdchoechuen O. An Improved Process for High Quality and Nutrition of Brown Rice Production. Food Sci and Techn Intern. 2010; 16: 147-158.
33. Kayahara H, Tsukahara K, Tatai T. Flavor, Health and Nutrition quality of pre-germinated brown rice. Royal Society of Chemistry. 2001; 274: 546-551.
34. Ito Y, Mizukuchi A, Kise M, et al. Postpradial blood glucose and insulin response to pre-germinated brown rice in healthy Subjects. J Med Ivest. 2005; 52: 159-164.
35. School of Medicine, University of Missouri 2024 New study shows diet, exercise reverses Liver damage.

ii. https://medicine.missouri.edu/news/new-study-shows-diet-exercise-

36. Jiamyangyuen S, Ooraikul B. The physico-chemical, eating and sensorial properties of germinated brown rice. Journal of Food Agriculture Environment. 2008; 6: 119-124.
37. Panlasigui LN, Thompson LU. Blood glucose lowering effects of brown rice in normal and diabetic subjects. Intl J Food Sci Nutr. 2006; 57: 151-158.
38. Sittipod S, Shi YC. Changes of starch during parboiling of rice kernels. J Cereal Sci. 2016; 69: 238-244.
39. Cho DH, Lim ST. Germinated brown rice and its bio-functional compounds. Food Chem. 2016; 1: 259-271.
40. Tuntipopipat S, Muangnoi C, Thiyajai P, et al. A bioaccessible fraction of parboiled germinated brown rice exhibits a higher anti-inflammatory activity than that of brown rice. Food Funct. 2015; 6: 1480-1488.
41. Biswas SK, Juliano BO. Laboratory Parboiling Procedures and Properties of Parboiled Rice from Varieties Differing in Starch Properties. Cereal Chem. 1988; 65: 417-423.

42. Buggenhout J, Brijs K, Oevelen JV, et al. Delcour, Milling breakage susceptibility and mechanical properties of parboiled brown rice kernels. LWT- Food Sci and Techn. 2014; 59: 369-375.

43. Okada T, Sugishita T, Murakami T, et al. Effect of the defatted rice germ enriched with GABA for sleepleness, depression, autonomic disorder by oral administration. Nippon Shokuhin Kagaku Kaishi. 2000; 47: 596-603.

44. Ito Y, Shen M, Hayamizu K, et al. Effect of pre-germinated brown rice on postprandial blood glucose and insulin level in subjects with hyperglycaemia. Jpn J Food Chem. 2005; 12: 80-84.

45. Patel M, Naik SN. Gamma-oryzanol from rice bran oil-A review. J Scientific and Ind Res. 2004; 63: 569-578.

46. Pereira MA, Jacobs DR, JPins JJ, et al. Effect of whole grains on insulin sensitivity in overweight hyperinsulinemic adults. The Am J Clin Nutr. 2002; 75: 848-855.

47. Reynolds AN, Akerman AP, Mann J. Dietary fibre and whole grains in diabetes management: Systematic review and meta-analyses. PLoS Med. 2020; 6: e1003053.

48. Hsu FT, Ming-Fu Wang MF, Yang MD, et al. Effect of pre-germinated brown rice on blood glucose and lipid levels in free-living patient with impaired fasting glucose or type II diabetes. Nutrition Science Vitaminol. 2008; 54: 163-168.

49. Imam MU, Ismail M, Omar AR, et al. The Hypocholesterolemic Effect of Germinated Brown Rice Involves the Upregulation of the Apolipoprotein A1 and Low-Density Lipoprotein Receptors Genes. J Diabetes Res. 2013; 2013: 134694.

50. Hamad S, Zafar TA, Sidhu J. Parboiled rice metabolism differs in healthy and diabetic individuals with similar improvement in glycemic response. Nutrition. 2018; 47: 43-49.

51. Parvin S, Hasan Q, Knudsen KEB, et al. Effects of Parboiling and Physico-Chemical Characteristics of Rice on the Glycemic and Insulinemic Indices in Type 2 Diabetic Subjects. Ibrahim Med Coll J. 2009; 2: 12-16.

52. Poquette NM, Wang YJ, Lee SO. Parboiled Brown Rice Product Reduces Postprandial Plasma Glucose Response in Men. J Nutr Food Sci. 2012; 2: 1-4.

53. Ripsin CM, Kang H, Urban RJ. Management of blood glucose in type 2 diabetes mellitus. Am Fam Physician. 2009; 79: 29-36.

54. Shyam S, Arshad F, Abdul GR, et al. Low glycaemic index diets improve glucose tolerance and body weight in women with previous history of gestational diabetes: a six months randomized trial. Nutr J. 2013; 12: 68.