

EFFECT OF PARBOILING ON GLYCEMIC IMPACT AND RESISTANT STARCH IN RICE (*ORYZA SATIVA* L.)

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BHUBANESWAR-751003, ODISHA**

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**EFFECT OF PARBOILING ON GLYCEMIC IMPACT AND
RESISTANT STARCH IN RICE (*ORYZA SATIVA* L.)**

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in Partial fulfilment of the Requirement
For the degree of**

**MASTER OF SCIENCE
IN
BOTANY**

By

Mr. Ajit Behera

Admission No.-04BOT/19



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2021



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CERTIFICATE

This is to certify that **Mr. Ajit Behera** bearing Roll No. - 04BOT/19, M. Sc., 2nd Year student of College of Basic Science & Humanities, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha has carried out his project work entitled “**Effect of parboiling on glycemic impact and resistant starch in rice (*Oryza sativa* L.)**” under my supervision and guidance for a period of six months for the partial fulfilment of the requirement for the Master in Science in Botany under College of Basic Science & Humanities, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha. This is bonafide research work has not been submitted by anyone else for any other degree or diploma to any other university nor institution.

I wish his all success in his future endeavour.

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This is to certify that the thesis entitled “Effect of parboiling on glycemic impact and resistant starch in rice (*Oryza sativa* L.)” submitted by Mr. Ajit Behera, bearing Roll No.- 04BOT/19 for the degree of Masters of Science in the subject of Botany of College of Basic Science & Humanities, Odisha University of Agriculture and Technology, Bhubaneswar is the result of bonafied research work done under my supervision. This thesis confirms to standard envisaged by the regulations of the university in my judgment. The work is an original piece of research undertaken by the candidate and the work has not been submitted earlier for any other Degree/Diploma. The thesis presented is adequate and merits consideration for the award of the degree for which it is submitted.

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Major Advisor



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CERTIFICATE-II

This is to certify that the thesis “Effect of parboiling on glyceemic impact and resistant starch in rice (*Oryza sativa* L.)” submitted by **Mr. Ajit Behera**, bearing Roll No. - 04BOT/19 to the College of Basic Science & Humanities, Odisha University of Agriculture and Technology , Bhubaneswar in partial fulfilment of the requirements for the degree of Masters of Science in the subject of Botany, has been approved by the Students’ Advisory Committee and the External Examiner.

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DECLARATION

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ABSTRACT

Rice is consumed by more than half of the world's population where it is the main source of nutrients and carbohydrates. Rice starch is hydrolyzed by enzymes in the digestive tract and converted into glucose which is the main energy source for metabolic functions. After meeting the energy requirement of the body, the extra calories from starch are stored as glycogen or fats for later use. Thus, rice is known to have higher glycemic index (GI) and glycemic load value. In many countries, parboiled rice is preferably consumed due to its nutritional superiority and lower starch digestibility rate. Processing of rice has an impact on its cooking quality and starch digestibility (GI, GL and resistant starch (RS)). The effect of parboiling on the aforementioned parameters was investigated in twenty rice genotypes with different traits. The cooking quality was improved in parboiled brown (PB) and parboiled milled (PM) rice. Parboiling has significantly ($P < 0.05$) reduced GI in both PB and PM rice with a proportionately increase in RS content. This study provide better insights on rice parboiling to reduce starch digestibility and improve minerals bioavailability which could be beneficial for diabetics and malnourished population.

Keywords: Rice, parboiling, glycemic index, glycemic load, resistant starch, cooking quality

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LIST OF ABBREVIATION

%	Percentage
µg	Microgram
µl	Microlitre
°C	Degree Celsius
AC	Amylose content
AMG	Amyloglucosidase
AUC	Area under curve
ASV	Alkali spreading value
BR	Black rice
CM	Centimeter
DOM	Degree of milling
DS	Digestible starch
DSC	Differential scanning calorimetry
G	Gram
GC	Gel consistency
GI	Glycemic index
GL	Glycemic load
GOPOD	Glucose oxidase peroxidase
H	Hour
HI	Hydrolysis index

Kg	Kilogram
L	Litre
M	Molar
Mg	Milligram
ml	Millilitre
Min	Minute
N	Normal
Nm	Nanometer
OD	Optical density
PB	Parboil brown
PM	Parboil milled
PGI	Predicted glycemic index
RS	Resistance starch
Rpm	Revolutions per minute
RB	Raw brown
RM	Raw milled
RS	Resistant starch
U	Unit
WU	Water uptake
WR	White rice

CHAPTER-1

INTRODUCTION

INTRODUCTION

Rice (*Oryza sativa* L.) is an important staple crop in most Asian countries where it is a major source of carbohydrate, micronutrients (Fe, Zn) and vitamins, offering wide prospects for value addition. Starch is the main carbohydrate component of rice, composed of amylose (linear polymer of α -D glucose units) and amylopectin (branched polymer of α -D glucose units). Rice is generally considered as a high glycemic index (GI) food which is associated with potential risks of type-II diabetes, obesity and cardiovascular disorders (Lal et al., 2012). Glycemic index is the property of starchy foods to raise the blood glucose level after consumption and foods can be categorized into three groups based on their GI values, i.e low GI (<55), medium GI (56-69) and high GI (>70) (Kumar et al., 2018). Regular consumption of foods that are rich in carbohydrates such as milled rice coupled with current lifestyle has increased risk of developing type-II diabetes. Varietal differences with varying levels of amylose content (AC) can produce rice having variation in GI values (Kumar et al., 2018). According to Fitzgerald et al. (2011) consumption of rice with low GI (<55) can result in a moderate increase in blood glucose concentrations, thereby improving insulin sensitivity and thus preventing from type-II diabetes. In the present scenario of increasing awareness regarding diabetes and obesity, low GI foods are preferred by consumers to control as well as to prevent type-II diabetes. The postprandial blood glucose response is affected not only by the ingested food's GI but also by the amount of carbohydrates present in it (Lal et al., 2021). Glycemic load (GL) is calculated as a product of GI and the total available carbohydrates of the test food. Based on GL, foods are classified as low GL (<10), medium GL (10-20) and high GL (>20) (Prasad et al., 2018). Thus GI and GL are considered as critical parameters for choosing the right diets for diabetic populations.

All kinds of starches ingested into the human body are not digested into glucose. The portion that resists this process is generally referred to as dietary fibre (Fuentes-Zaragoza et al., 2010). In 1982, while standardizing an *in vitro* method for non-starch polysaccharides estimation, Englyst and co-workers found that some starches resist enzymatic hydrolysis which was called Resistant starch (RS). This kind of starch, therefore, passes through the small intestine, enters undigested into the colon, where it is used as a substrate for microbial fermentation and results into short-chain unsaturated fats, carbon dioxide, hydrogen and methane. At present, RS has been classified into five groups. Type 1 RS is physically trapped starch so that digestive enzymes would be prevented from approaching them. This can happen

in whole or partially milled grains, seeds, legumes and cereals (Sullivan et al., 2017). Type 2 RS is the tight-packed form of starch within the starch granules which resists attack by digestive enzymes. This form of RS is commonly found in bananas, raw potatoes and maize starch (Zaman & Sarbini, 2016). Type 3 RS is the retrograded form of starch, which forms when cooked starchy foods are cooled. The cooling allows the starch segments (amylose and amylopectin) to undergo the process of retrogradation that reduces digestibility. Type 4 RS is one that has reduced digestibility because of chemical treatment/modification (esterification or cross-linking) of starch (Zaman & Sarbini, 2016). Finally, type 5 RS (in rice) which was discovered over the past five years, is starch wherein the amylose component forms complexes. The GI and RS content are two significant markers of starch digestibility. The RS is slowly digestible and is negatively correlated with the GI. Increasing RS of a food/food combination can be used as a method to reduce the absorption of glucose (Kumar et al., 2018). The RS reaches the small intestine and decreases postprandial glucose and insulin responses. This has noteworthy ramifications for utilizing RS in diet plans for the diabetics. Foods that have high RS content are digested slowly compared to similar foods containing higher concentrations of either slowly digestible starch or rapidly digestible starch. Therefore, RS has the potential to be a part of management and treatment programs to control type II diabetes and manage weight loss (Zaman & Sarbini, 2016). Thus, incorporation of high RS food in the human diet has significant potential in combating diabetes and ensuring better bowel health.

Milled (white) form of rice is generally preferred by the majority of the population. However, milled rice is considered a nutritionally poor product. As most of the nutrients found in rice grain accumulate in the outer aleurone layer and embryo which removes during the de-hulling and milling process. As a result, diets over-reliant on white rice risk deficiencies for several nutritional components (Mir et al., 2015). Various processing methods such as parboiling, ageing, germination, puffing, flaking, cooking and cooling could alter the starch digestibility and minerals bioavailability of rice grain (Mir et al., 2015). In many Asian and West African countries, people prefer to eat parboiled rice over milled rice (Taleon et al., 2020; Zohoun et al., 2018). Parboiling is a hydrothermal treatment of rice grain at atmospheric pressure that involves three main steps: soaking of paddy in hot water below the degrees of its gelatinization temperature, steaming the hydrated paddy and drying to 12-14% moisture content (Zohoun et al., 2018). During parboiling, starch granules are gelatinized and retrograded as a result various changes occur in rice kernel, which affects its overall quality parameters. Parboiling treatment principally brings the characteristic change in rice grain such as milling, cooking, storage and eating qualities (Mir et al., 2015). The treatment also alters the structural properties of rice starch, getting converted from crystalline to amorphous form and

resulting in the highly compact and translucent endosperm (Sivakamasundari et al., 2021). Parboiling is also known to increase the levels of RS which helps in reducing starch digestibility that is reflected in the lower GI and GL value of rice (Cheng et al., 2019). GI, GL, RS and cooking quality are affected by parboiling but the magnitude of effect has not been evaluated under milling and parboiling conditions.

The following were the objectives of the present study:

- 1) To study the effect of parboiling on the cooking properties and starch digestibility in rice genotypes with different traits.

- 2) To study the variation of Resistant starch and cooking quality parameters in rice and its relationship with Glycemic index.

CHAPTER-2
REVIEW OF LITERATURE

REVIEW OF LITERATURE

I. Glycemic index and Glycemic load:

II. Resistant starch:

III. Cooking quality of rice:

IV. Milling and Parboiling of rice

The cultivated rice plant, *Oryza sativa* L., is an annual grass belongs to family Gramineae. The leaves are lengthy and flattened, and its panicle or inflorescence is made from spikelets having flowers that give the grain. Many cultures have evidence of early rice cultivation, including China, India, and the civilizations of Southeast Asia. However, the earliest archaeological evidence comes from central and eastern China and dates to 7000-5000 BC. The exception type called upland rice, the plant is grown on submerged land in the coastal plains, tidal deltas, and river basins of tropical, semitropical, and temperate regions. After wheat, rice grain is the second largest food grown in the world; composed with wholesome nutritious cereal grain possesses unusual dietary requirements. It is also free from gluten and cholesterol and contains traces of fat and sodium contents. It also contains complex carbohydrates which is easily digestible. With increase in population the global demand for rice is rising, increasing affluence and changing dietary habits. About 95 % of the world's rice grain is eaten as whole kernel by humans and around one-half of the world population (including all of East and Southeast Asia) is wholly dependent upon rice as a staple food. Rice is most vital cereal food crop of India, which occupies about 24% of gross cropped area of the country where it contributes 42% of total food grain production and 45% of total cereal production of the country.

The amino acid rating of wild rice proteins was determined to be 81 – 84 (Wang, et al.,1978), depending among others on the wild rice species. Lysine is most usually defined because the first restricting amino acid and threonine as second restricting amino acid (Zhai et al., 1994) Juliano et al., in 1973 reported that the protein content (% N x 5.95) of different rice varieties such as Kalijira (Aman) is 10.3%, Kullankar Adt 23 is 11.2%, ARC 10525 is 8.4%, Kolamba 5 is 6.8%, IR8 is 8.2%.The lipid content of wild rice is normally described to be low as compared to different cereal grains. In the early literature, the wild rice lipid content is defined to be among 0.5 - 0.8% . Approximately one third of the fatty acids is created from the essential fatty acid linolenic acid (Lorenz, 1981) because the content of linoleic acid excessive and more than two-thirds of the fatty acids are polyunsaturated. More current

studies, finds that 20.1 – 31.5% linolenic acid and 35.0 – 37.8% linoleic acid in lipid parts of industrial wild rice samples from the US and Canada (Przybylski et al., 2009). Resistant starch is taken into consideration a form of nutritional fiber. It has been proven that the fermentation of resistant starch by using gut microorganisms outcomes in the formation of comparably excessive concentrations of butyrate within large intestine. The wild rice gelatinization temperature is higher than that of wheat but comparable to rice (*O. sativa*). Also, Hoover's data do not support this hypothesis, since they determined a much lower gelatinization range for wild rice starch (51 – 64 °C). In the same study they determined a gelatinization range of 70 – 79 °C for long grain brown rice (*O. sativa*). Lorenz, Hoover's group found native wild rice starch to be nicely degraded via amylases. Hoover and co-workers found wild rice starch is resistant to retro gradation (Sailaja et al.1996). Zhai et al. reported zinc concentrations of 2.8 and 2.5 mg/100 g for two North American wild rice samples (Zhai et al., 2001) and zinc levels between 1 and 4 mg/100 g were found in commercial wild rice samples bought in the US (Nriagu, J.O,1995). Zinc levels were between 4.0 and 12.1 mg/100 g, a level twice as high as that found in oats and wheat and three times higher than in corn (Lorenz et al., 1981). Other important minerals such as iron and copper seem to arise in similar (sometimes slightly lower) levels in wild rice as compared to different cereal grains, whereas calcium concentrations slightly lower (Oelke et al., 1997).

2.1 Rice Starch Digestibility:-

Cooked rice is effortlessly digested as it carries a higher percentage of digestible starch (DS) and a lower percentage of resistant starch (RS) Higher percentage of digestible starch increases the glucose level exorbitantly in the blood stream. High level of glucose in the blood stream increases the insulin pressure and prevalence of high insulin pressure in long term makes cells as insensitive to insulin and it causes Type II diabetes. Type II diabetes is a Foremost international health trouble and its incidence is growing dramatically throughout the world, especially in Asia (Chan et al., 2009; Danaei et al., 2011). According to International Diabetic Federation, 2012, 63 million people in India and 92.3 million people in China are diabetic. With the aid 2030, nearly 330 million people will be affected by diabetes and the greatest burden of this disease will be borne frequently by the socio-economically disadvantaged in low and middle income societies (Misra et al., 2010; Walgate 2008). G Selvakumar et al.,(2014) reported that the resistance starch content of different rice varieties such as Ratna(5.2%),IR 56(6.0%), Pranava(6.8%), Thattaravella(4.7%), IR 20(3.7%), sNorungan(9.5%), Mudgo(7.3%),Mahalakshmi(3.1%)Jeeraga sambha(4.1%),Chinna

ponni(2.8%). Physicochemical and metabolic properties of rice are influenced by numerous factors. One of these factors is amylose content, which is often used to predict starch digestion rate, blood glucose and insulin responses to rice. Starchy foods that are rich in amylose content are associated with lower blood glucose levels and slower emptying of human gastrointestinal tract compared to those with low levels of amylose (Behall, Scholfield, & Canary, 1988; Behall, Scholfield, Yuhaniak, & Canary, 1989; Frei, Siddhuraju, & Becker, 2003). Apart from amylose, resistant starch (RS) has recently received much attention for both its health benefits and functional properties. RS has been defined as “the sum of starch and products of starch degradation not absorbed in the small intestine of healthy individuals” (Muir et al., 1993). It positively influences the functioning of the digestive tract, microbial flora, the blood cholesterol level, the GI and assists in the control of diabetes (Fuentes-Zaragoza, Riquelme-Navarrete, S_anchez-Zapata, & P_erez-_Alvarez, 2010). The rate and extent of hydrolysis in the small intestine are both important nutritionally. An altered rate of hydrolysis in the colon may lead to the desired resistant starch fermentation occurring in the different portion of the colon, with any physiological effects of the fermentation products accruing to the specific colonic region. RS directly passes into the colon where it can be fermented via natural microflora to short-chain fatty acids such as butyric acid (Baghurst et al., 1996). RS is a non-caloric ingredient and does not contribute to increase in blood glucose. In this, it has physiological result inside human body which are similar to that of dietary fiber, which has been shown to reduce risks for some diseases, including colon cancer, coronary heart disease and glycemia (Champ *et al.*, 1999; Ranhotra *et al.*, 1996)

2.2 The Glycemic Index And Glycemic Load of Rice:-

How your body handles sugar is estimated by glycemic index (Peter Nickless et al. 2014) and how they compare to glucose is measure through a rating that given to the foods. Glucose has a maximum rating of 100. High- glycemic foods, will have a score of 70 and above, such as white bread. Medium-glycemic foods, such as raisins, will have a score of 56-69 and low-glycemic foods having glycemic index of 55 or lower such as peanut. High – glycemic foods consumption over time leads to reduce your ability to control blood sugar and conditions, such as diabetes. It is best to consume lower 70 glycemic index food. The quantity of carbohydrates in a mixed meal is measured by glycemic load (GL) and can be used in addition to glycemic index, which only reflects the quantity of carbohydrates(Monro JA et al. 2008). Glycemic load of rice is calculated as its net available carbohydrates content in a serving size, multiplied by sample’s glycemic index, and divided by 100(Venn et al. 2006). The different varieties of rice will have different glycemic index ratings. White rice has a

glycemic index of 79, which makes it a excessive-glycemic index food. Brown rice has a glycemic index of 55, making it a low-glycemic index food. Basmati rice is 52 making it also a low-glycemic food. GI, or glycemic index, measures the capacity of carbohydrates to raise blood sugar degrees after eating. Foods with a excessive GI are more easily absorbed through the body that bring about in blood sugar fluctuations leading to an improved risk conditions like diabetes. Low GI foods are absorbed at a slower rate, causing a gradual release of sugar into the blood. The chemical composition and in vivo glycemic potential of popular Indian rice varieties namely Jaya, Lalat, NDR-97, PR-113, Salivahana, Sasyasree, Savithri, Tellahamsa, Triguna, Varalu and one hybrid DRRH-3 studied by V.S.S. Prasad et al (2017). He found that Resistant starch (RS) content (2.03–2.91%) correlated negatively with the glycemic index (GI) ($r = -0.674$; $p = 0.05$) and contributed for 45.5% of GI variability. Lalat, with 2.91% RS and 27.9% amylose changed into the best one eliciting low GI of 50 and glycemic load (GL) of 13 even as the rest exhibited GI ranging from 70 by Savitri to 80 by Salivahana. He concluded that low GI variety is Lalat which of importance in the nutritional prevention and control of diabetes.

Siti Dewi Indrasari et al (2010) the changes in lifestyle and food intake pattern have led to increasing degenerative diseases, such as diabetes mellitus. Rice intake should be limited in the diet for person with the diabetes type 2, due to opinion that rice is considered as a hyperglycemic food. Rice varieties indicate wide range glycemic index (GI) values. Calculation of rice GI values was achieved in March to July 2007 at the Grain Quality Laboratory of the Indonesian Center for Rice Research (ICRR) in Sukamandi, West Java. The objective of the study was to calculate the GI values of nine rice varieties, such as, Aek Sibundong, Setail, Ketonggo, Air Tenggulang, Martapura, Cigeulis, Batang Lembang, Margasari, and Cisokan. The characterization of rice grains varieties included physical and milling quality, cooking qualities, proximate analysis, amylographic profiles, in vitro starch digestibility, crude fiber contents, fiber contents, and GI values. The results showed that characteristics of the quality components of the rice varieties varied considerably. The protein contents ranged from 8.8% to 10.55% (db), the soluble fiber contents 3.00-3.87%, non-soluble fiber contents 3.94-7.49%, and starch digestibility 53.65-57.45%. Two out of nine varieties that have low amylose contents were in the category of high GI values, i.e. the black glutinous rice Setail (GI = 74) and the white glutinous rice Ketonggo (GI = 79) The rice with medium amylose contents has medium GI values, i.e. Aek Sibundong (GI = 59) and Cigeulis (GI = 64) The other five rice varieties, i.e. Air Tenggulang (GI = 50), Martapura (GI = 50), Batang Lembang (GI = 34), Margasari (GI = 39), and Cisokan (GI = 34) were in the category of low

GI values. Low GI values of rice varieties are suggested as a better alternative for the daily diet of diabetes type 2 patients. There seems to be a positive correlation between high amylose content and low GI value. G.M. Somaratne et al. (2017). Four distinct pigmented dark-red (red) and non-pigmented white basmati rice samples were examined. Red and white basmati varieties can be classified as low GI and medium GI rice, respectively. The degree of polishing had no effect on the GI. Kaye Foster-Powell et al.(2002) Reliable tables of glycemic index (GI) compiled from the scientific literature are instrumental in improving the quality of research examining the relation between GI, glycemic load, and health. The GI has proven to be a more useful nutritional concept than is the chemical classification of carbohydrate (as simple or complex, as sugars or starches, or as available or unavailable), permitting new insights into the relation between the physiologic effects of carbohydrate-rich foods and health. Several prospective observational studies have shown that the chronic consumption of a diet with a high glycemic load (GI dietary carbohydrate content) is independently associated with an increased risk of developing type 2 diabetes, cardiovascular disease, and certain cancers.

2.3 Resistance starch:-

Resistant starch (RS) changed into first diagnosed as a complicating thing within the determination of total dietary fiber (TDF) degrees by the Prosky Method (Englyst et al., 1987). RS has been defined as the fraction of starch, which escapes digestion inside the small intestine, and can be digested inside the large intestine (Englyst et al., 1992). This is much like to the traditional definition, except for the qualification that fiber is non-starch in origin. A range of things that make contribution to starch's resistance to digestion, which have led to four categories, each with similar resistance properties.

They are as follows.

RS1: physically inaccessible to digestion by entrapment in a non-digestible matrix;

RS2: ungelatinized starch;

RS3: retrograded starch;

RS4: chemically modified starch

RS5: Thermostable starch

Resistant starch type 1 (RS1) is composed of bodily trapped starch. These starch granules are physically bodily trapped in the food matrix so that the digestive enzymes are averted or delayed from having access to them. This can arise in entire or partially ground grains, seeds, cereals, and legumes (Lineback, 1999) .

Resistant starch type 2 (RS2) refers to native resistant starch granules which includes those usually discovered in bananas, raw potatoes and amylose maize starch. These native starch granules are recognised to withstand attack by α -amylase. Berry first confirmed that the amylose degree in maize starches typically correlates with resistant starch levels (Berry, 1986) Additionally, it turns into also stated that the granular size of excessive amylose starch affects the digestibility. Smaller granules have lower digestibility (Knutson *et al.*, 1982) .

Resistant starch type 3 (RS3) is made up of retrograded starch. The starch components (amylose and amylopectin) go through the procedure of retrogradation in a time dependant process after the starch has been cooked or gelatinized. Although, RS3 is frequently attributed to amylose retrogradation (Sievert and Pomeranz, 1989; Eerlingen *et al.*, 1993), retrograded amylopectin has additionally been proven to contribute to type 3 resistant starch (Eerlingen *et al.*, 1994; Russell *et al.*, 1989) . Most amylose-containing starches can be processed through heat and moisture to produce some type 3 resistant starch. For example, wheat starch will produce low levels of resistant starch as an example result of gelatinization and cooling in bread baking (Rabe and Sievert, 1992; Bjorck *et al.*, 1986) In one recent review focusing on resistant starch type 3 (Eerlingen and Delcour, 1995) the authors stated that RS3 was shown to be “thermally very stable”, and was isolated by the TDF method (Total dietary fiber) These authors subsequently noted that “highly resistant” fractions are those that resist hydrolysis at 100°C. Sievert and Pomeranz (1989) described the use of autoclave/cooling cycles to produce resistant starch. They studied the autoclaved starches and resistant starch isolated by the TDF method, and showed that the high temperature Differential Scanning Calorimetry (DSC) endotherm of the intact starches correlated with a similar endotherm from the RS. Based on polymer crystallization theory, it is (Eerlingen *et al.*, 1993) hypothesized that the formation of type 3 resistant starch can be considered as a crystallization process of amylose in a partially crystalline system. Multi-cycle autoclaving of starch-based products results in retrogradation, and consequently increased levels of RS3, particularly in high amylose foods (Skrabanja and Kreft, 1998) .

Resistant starch type 4 (RS4) It is defined as chemically modified starch. This is a surprisingly more recent classification of resistant starch that refers to- a chemically changed or re polymerised starch. (Croghan, 1994) Chemical modification allows the technology of distarch phosphodiester cross-linkages which may be modulated to produce merchandise of 40 % - 80 % resistant starch by using the entire dietary fiber method (Seib and Woo, 1999) .

Resistant starch type 5 (RS5) is a type of RS is starch wherein the amylose component forms complexes with lipids (amylose-lipid complex),which makes it more thermally stable . Digestibility of cooked rice starch is usually determined by the amount of amylose in the grain. The more amylose there is, the slower is the digestion of rice and the lower is the glycemic index , which indicates the effect on blood sugar. However, in rice with type 5 RS, such starch may take several hours to digest or not at all, like a form of dietary fiber . This is because the amylose-lipid complex in type 5 RS restricts swelling of the starch granule during cooking, making it resistant to hydrolytic enzymes .

Table 1

Classification of types of resistant starch, food sources and factors affecting their resistance to digestion.

Type of RS	Description	Food sources	Resistance reduced by
RS1	Physically protected	Whole- or partly milled grains and seeds, legumes, Pasta	Milling, chewing
RS2	Ungelatinised resistant granules with B-type crystallinity and are hydrolysed slowly by a amylases	Raw potatoes, green bananas, some legumes, high amylose starches	Food processing and cooking
RS3	Retrograded starch (<i>i.e.</i> non-granular starch-derived materials)	Cooked and cooled potatoes, bread, cornflakes, food products with prolonged and/or repeated moist heat treatment	Processing conditions
RS4	Chemically modified starches due to cross-bonding with chemical reagents, ethers, esters, etc.	Some fibre-drinks, foods in which modified starches have been used (<i>e.g.</i> certain breads and cakes)	Less susceptible to digestibility <i>in vitro</i>
RS5	Amylose lipid complex	Foods with high amylose content	Immiscible structure by lipid around starch granules

2.4 Rice grain processing:-

i. Rice Milling:-

Milling is an important processing step of rough rice, which is usually completed to produce milled, polished grain because of consumer choice. Milling of rough rice is normally performed at about 14% dry basis moisture content to produce polished edible grain (Bhattacharya et al.,2011). The reason of milling is to remove the hulls and bran from harvested, dried rough rice and to produce milled or polished rice with a minimal breakage. First, rice outturn depends at the husk content of paddy. High husk content material ends in the much less rice yield. Most rice types have husk content inside the variety of 19–22% (Yadav et al.,2008). Second, rice outturn depends on the degree of milling (DOM). The quantity of elimination of the bran layers is termed DOM, which determines the whiteness of rice. In rice milling, rough rice is dehusked to obtain brown rice, that's subjected to abrasive or friction pressure to do away with bran layers from the endosperm. The greater brown rice is polished, the less is rice outturn and the much less brown rice is polished, greater is the outturn. The parboiled rice required more energy for milling as compared to raw rice (Billiris et al.,2012). The milled rice kernel whiteness increases appreciably with accelerated removal of bran layer during milling (Park et al.,2001). Third and through a long way of best significance is the breakage of rice for the duration of milling. Head rice yield is reduced with increase duration of milling (Liang et. al.,2008). Nutrient losses mostly arise at some point of the milling operation, due to the fact these mostly concentrated in the outer layers of bran. The losses of lipids, proteins, vitamins and minerals expand extensively as the DOM increased (Rohrer et al.,2004). During the milling process from brown rice to white rice, the losses of proteins and overall minerals reached 28.6% and 84.7%, respectively (Lamberts et al.,2007) Prom-u-Thai et al.2007 reported that milling process resulted in 25–84% iron loss from different rice varieties.

ii. Rice parboiling:-

Parboiling technique is a hydrothermal treatment of rough rice, which commonly entails soaking, steaming and drying operations (Bhattacharya et al., 2004) Parboiled rice is one of the most popular rice products and turns into more vital no longer most effective for it's stronger nutritional value however also by the improved cooking and techno-functional properties, which might be preferred from the industrial point of view for different types of products (Oli et al.,2014) The parboiling technique exhibits several advantages over unparboiled rice inclusive strengthening of kernel integrity, improved milling yield, prevention loss of nutrients during milling operation, improved shelf life as well as prevention of the proliferation of insects (Oli et al., 2014 and Demont et al., 2012) It additionally helps to reduce the stickiness of cooked rice and improves the cooking behaviour of the parboiled rice (Buggenhout et al, 2013 and Islam et al,2004) . Paddy is completely hydrated at some point of the soaking process in pre-heated water and is generally implemented to enhance water diffusion into rice grain for gelatinization (Dutta et al., 2012). Soaking procedure in pre-heated water for saturation was found to improve the cooking level of rice (Dutta et al., 2014) because water makes starch granule sufficiently swell to be gelatinized. The primary cause of steaming system is to gelatinize the soaked rough rice. The steamed rice is then dried to about 14% moisture for safe storage and milling. The drying has profound have an impact on the milling quality of the product. The drying method for parboiled rice is much greater intense than for raw paddy with less risk of breakage during milling (Buggenhout et al., 2013).

Parboiling significantly influences the axial dimensions of rice grain (Mir et al.,2016). The water diffusion together with warmness treatment causes the irreversible swelling of starch granules and hence the parboiled rice kernel after drying is thicker and shorter than non-parboiled counterpart (Bhattacharya et al.,2011). It has been located that the size and shape of the milled parboiled rice grain have been slightly distinctive from ones of the raw milled rice. The former turned into little shorter and little fatter than the latter (Dutta et al., 2014). Parboiled rice grains are fairly glassy and translucent. The opaque white patches seen at the belly of the milled rice known as chalkiness is the result of cellular morphology of starch granules, whereby chalky grains have packed loosely starch granules leaving some air spaces that scatter light and looks opaque (Islam et al., 2001). Chalkiness is a noticeably unwanted property of rice varieties. Because of the loose packing of starch free volume is more within the kernel which can take extra water than normal types. The water diffusion and starch gelatinization method through parboiling eliminates such air spaces and for this reason reduces the chalkiness of rice grain (Bhattacharya et al.,2011). Parboiling reduces the breakage of rice

grains during milling operation, that is the primary advantage of this process (Bello et al., 2006 and Delcour et al., 2012) . The head rice yield of rice in particular depends on the parboiling situations and the resulting modifications in physicochemical properties of rice grain during parboiling. The principal physical change taking place in the rice kernel after parboiling is the growth of hardness. The parboiling schedules consisting of temperature and duration have the significant impact on hardness of rice kernel. The hardness cost of the rice kernel is increased with the growth of soaking temperature (Mir et al.,2013) and steaming time (Islam et al.,2001). Parboiling treatment additionally increases the tensile strength and modulus of elasticity of the rice grain. Parboiling process changes organoleptic properties of rice kernel. Colour change in parboiled rice improved with increasing of soaking water temperature (Islam et al.,2004 and Mir et al.,2013 and Sareepuang et al.,2008) and increasing steaming duration as well as the increasing steaming pressure of hydrated grains (Oli et al.,2014). The colour change in rice grain is especially caused by maillard reaction, diffusion of husk pigments in the endosperm during soaking and processing conditions in parboiling which determines the intensity of colour (Dutta et al.,2012).

CHAPTER-3
MATERIALS AND METHODS

MATERIALS AND METHODS

3.1 Plant materials and sample processing

Rice grains of 20 genotypes (with different traits) were obtained from the Crop Improvement Division, ICAR-National Rice Research Institute (ICAR-NRRI), Cuttack. The paddy grains moisture level was brought to 14 % before processing. The moisture level was analysed with a moisture analyzer (AND MX 50, A&D Company Ltd, Tokyo, Japan) For parboiling process, the raw grain (1kg) was soaked in distilled water (4-5 °C) for 8 to 9 h. After draining of water, it was steamed for 30 min at 100 °C under normal atmospheric pressure. Subsequently, the grains were sundried for 6-7 h to attain 12-13 % moisture content. After dehusking with the help of a laboratory-grade hulling machine (Satake Pvt. Ltd., Japan), followed by parboiling of rice. The parboiled rice was milled (10 %) in the miller (Satake grain testing mill, Tm-05, no. 554023, Japan). The rice grain was powdered using an electric blender (Icon Classique mixer grinder C, HP/14/001/0064; Morphy Richards, India) and sieved with the help of 100 mesh size. To estimate different parameters such as cooking quality parameters, GI, GL and RS, the rice powder was used.

3.2 Estimation of cooking properties of rice

The grain cooking parameters i.e. alkali spreading value (ASV), gel consistency (GC), water uptake (WU) and amylose content (AC) were determined as per standard procedures (Kumar et al., 2020).

Alkali Spreading value(ASV) and Gel consistency (GC)

Six milled rice grains were placed in a Petri dish containing 10 mL of potassium hydroxide (19.54 g of potassium hydroxide dissolved in 1L of DW) The dish was incubated at 27-30°C for 23 hours after which the ASV was recorded on a seven point scale. For estimation of GC, 100 mg of rice flour was taken in long test tube (2×19.5 cm) and 0.2 mL of ethanol (containing 2.0 mL of 2.8 g of KOH dissolved in 250 mL DW and 0.25% thymol blue) was added. The tube was kept in boiling water bath for 7 min and allowed to cool. The contents were mixed well and kept in ice bath for 15 min. Later, the tube was removed and laid horizontally on a graph paper for one hour after which the spreading of gel (mm) was recorded.

Water uptake

Two g of rice samples were taken in graduated test tubes containing 10 mL of distilled water and soaked for 30 min. It was boiled for 45 min at 77 to 80°C in a temperature water bath. Two to three test tubes (without rice grains) with 10 mL of distilled water were kept as control in the water bath. Immediately after boiling, the tubes were put in a beaker containing cold water for cooling. After cooling, the supernatant was poured into graduated cylinder and water level was noted. Water uptake was calculated using the following formula: $\text{Water uptake} = 100 / 2 \text{ g} \times \text{actual water absorbed}$.

Amylose content

Rice powder (0.1 g) was wetted with 1 mL ethanol and 9 mL of 1N sodium hydroxide and boiled for 10 min. After this, the volume was made to 100 mL with distilled water. A 5 mL sample from this digest was taken into a 100 mL volumetric flask to which 1ml of 1N acetic acid and 2 mL of iodine solution (1 g iodine and 10 g potassium iodide dissolved in 500 mL distilled water) were added. The mixture was incubated in dark for 20 min, after that diluted to 100 mL. The absorbance was read at 620 nm.

3.3 Determination of Glycemic index and Glycemic load

The *in vitro* GI estimation method modified in our laboratory (Molecular Biochemistry Laboratory, ICAR-NRRI, Cuttack, India) was used to determine the hydrolysis index (HI) and to calculate the GI value (Kumar et al., 2018a) For this, 200 mg rice powder (in triplicate sample) was heated with phosphate buffer (5mL, 0.1M, pH 6.9) for two minutes. The pH was then adjusted to 2.5 using o-phosphoric acid (10%) followed by addition of pepsin (200 µL) and incubated at 37°C in a water bath shaker for 1 hr at 110 rpm. The pH was readjusted to 6.9 with potassium hydroxide for providing optimum condition for α-amylase (200 µL) activity. The entire contents were shifted to a cellophane dialysis tube (length, 24.26 mm and diameter, 14.3 mm) which was placed in a falcon tube (50 ml) containing 40 mL phosphate buffer (0.1M, pH 6.9) and incubated at 37°C on a water bath shaker with continuous shaking at 110 rpm. The dialysis tube was used to mimic the human small intestinal condition, which also avoids the need to denature the digestive enzyme present in the samples drawn for analysis. An 0.5mL aliquot was withdrawn from the dialysate at 30 min intervals regularly up to 180 minutes and treated with amyloglucosidase (AMG) (30 µL) for 30 min. The released glucose was measured using glucose oxidase/oxidase (GOPOD) reagent (Megazyme International Ltd, Bray, Ireland) The absorbance was recorded at 510 nm in a spectrophotometer (Model Specord 210 Plus, Analytik Jena AG, Germany) For reference carbohydrate, D-glucose was used.

The Hydrolysis index (HI) was calculated by dividing the area under the curve (AUC) of sample by that of the D-glucose. The predicted glyceic index (PGI) was calculated by the given formula (Goni et al, 1997).

$$\text{PGI} = 39.71 + (0.549 \times \text{HI})$$

Glycemic load of rice sample was calculated by the following formula:

$$\text{GL} = \frac{\text{GI} \times \text{Net available carbohydrate per serving size (150 g)}}{100}$$

3.4 Estimation of Resistant starch

The RS content was estimated using the resistant starch assay kit (K-RSTAR) (Megazyme International Ltd, Bray, Ireland) as per their methodology with few modifications. Rice flour (0.1 g) was digested with 4 mL of a solution containing pancreatic α -amylase (10 mg/mL in 100 mM Tris-maleate buffer, pH 6.0) and AMG (300 U/mL) in a 25 mL conical flask with vigorous shaking at 250 rpm for 16 h at 37°C. After this, 4 mL of absolute ethanol (99%) was added, vigorously stirred and the contents were transferred to an Oakridge tube followed by centrifugation at 3000 x g for 10 min. The pellet was swirled with 6 mL of ethanol (50% v/v) and centrifuged again at 3000 x g for 10 min. The pellet was re-suspended in 2 mL of 2M potassium hydroxide (MP Biomedicals) in an Oakridge tube and stirred on an ice bath for 20 min. After this, 8 mL of 1.2M sodium acetate buffer (pH 3.8) was added followed by addition of 0.1 mL of AMG (3300 U/mL) The tubes were incubated at 50°C for 30 min and centrifuged at 3000 x g for 10 min. An aliquot measuring 0.1 mL was mixed with 3 mL of GOPOD reagent and incubated at 50°C for 20 min. The absorbance was recorded at 510 nm. The RS content was estimated using the formula provided in the manufacturer's protocol.

CHAPTER-4
RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

4.1 Effect of parboiling on cooking quality of rice:

The reasons for the increase in the number of diabetic patients have been attributed to changes in diet and physical activity levels brought by economic development, industrialization and urbanization. Among dietary factors, the role of dietary carbohydrates, particularly the quantity and quality of the staple cereal, has received widespread attention. The information on the relationship between starch digestibility and cooking qualities of rice may be important for health practitioners who have the responsibility of advising diets that give controlled glycaemic response (Kale et al., 2017). WU, ASV, AC and GC are the important parameters that influence the cooking quality of rice. The effect of parboiling in these cooking parameters of brown and milled rice was assessed. Amylose content in the raw brown (RB) rice ranged from 9.82 % in Mamihunger to 24.62 % in Heera (Table 2) After parboiling, the AC was marginally decreased in parboiled brown (PB) rice which is attributed to the leaching of amylose and other solid components during the soaking and steaming process (Patindol et al., 2008). After milling, the AC was increased in both raw milled (RM) and parboiled milled (PM) rice compared to brown rice (Table 3) which is attributed to the debranching of amylopectin during heat treatment and formation of linear structure which help in reducing starch digestibility (Zohoun et al., 2018). Mir et al., (2015) reported that amylose leached in the soaked water would easily retrograde when the cooked rice is cooled and form type-3 RS that can help in reducing the GI of rice. Water uptake values of RB rice was ranged from 75 mL/ 100 g in Lalat to 115 mL/100 g in Manipuri black. The WU value was decreased after parboiling in all genotypes (Table 2 and Table 3) In RB rice, starch granules are separated by inter-granular spaces which absorb water quickly during the heating and cooking process. During heating, the granules absorb water with a proportional swelling that ends with granule deformation and paste formation (Kale et al., 2017). In excess water, grains become soft upon complete gelatinization. In parboiled rice, some grain granules are partially gelatinized, sealing up the inter-granular spaces and existing fissures on the grain. This forms compact grains which absorb water less during cooking with a consequent decrease in the swelling rate and softening of the rice grains (Sivakamasundari et al., 2020). Furthermore, amylose and protein barriers have also been suggested to restrict heat-induced swelling during cooking or parboiling (Kale et al., 2017) explaining why parboiled samples recorded lower Volume expansion compared to the non-parboiled rice. Alkali spreading value of RB rice genotypes was ranged from 3 to 5 while after parboiling, their ASV value found to increase in both PB and PM Rice (Table 2 and

Table 3) Gel consistency test of rice flour measures the tendency of the gelatinized starch granules to retrograde on cooling. Results indicated that there also existed some differences among tested rice genotypes. Gel consistency among these genotypes in RB ranged from 43 mm in Heera (hard type) to 72 mm in Mamihunger (soft type) After cooking parboiled rice, the GC value was found to increase in both PB and PM rice because their starch was partially gelatinized during heat processing (Table 2 and Table 3) All the genotypes having lower to intermediate AC generally showed soft to medium GC while high amylose genotype like Heera (AC- 24.62 %) was always linked with hard or medium GC (Mir et al., 2015; Sivakamasundari et al., 2020; Sivakamasundari, et al., 2021).

Cultivars	Water uptake (mL/ 100g)		Alkali spreading value		Amylose content (%)		Gel consistency	
	RB	PB	RB	PB	RB	PB	RB	PB
Chinikamini	95	65	3	5	21.70	21.15	49	59
Naveen	85	75	3	5	21.92	20.02	52	57
Bindli	110	105	3	5	17.10	16.50	59	65
CR Dhan 310	95	85	3	5	19.70	19.65	57	60
Taraori basamati	85	75	3	5	20.10	19.72	53	56
Arc 10075	90	75	3	5	20.97	19.20	53	58
Sahabhagi	90	85	3	5	19.50	18.52	55	59
Mami hunger	115	110	3	6	9.82	9.75	72	75
Nua dhusara	105	95	3	5	15.75	13.42	67	69
Nalbora	95	90	5	6	14.67	13.95	69	70
Manipuri black	115	95	3	7	12.82	11.25	70	73
Masuri	90	85	3	5	16.45	14.25	64	68
Pusa basamati	110	105	5	6	18.15	16.95	59	65
Heera	90	85	3	5	24.62	23.40	43	48
Lalat	75	65	3	5	20.40	19.95	53	55
Geetanjali	90	85	3	6	19.57	19.05	50	55
Mornodoinga	105	95	3	6	23.90	21.82	49	54
Swarna	85	75	3	5	23.80	21.75	47	52
CR Dhan 311	95	85	3	5	19.52	18.45	56	60
PB-177	90	85	3	6	20.70	19.05	59	61

RB: raw brown; **PB:** parboiled brown

Table 2: Grain quality analysis of raw brown and parboiled brown of twenty genotypes of rice.

Cultivars	Water uptake		Alkali spreading value		Amylose content		Gel consistency	
	RM	PM	RM	PM	RM	PM	RM	PM
Chinikamini	105	75	3	5	22.90	22.35	52	60
Naveen	115	80	3	5	24.97	24.75	55	62
Bindli	120	115	3	5	19.85	18.82	60	66
CR Dhan 310	105	90	3	5	20.87	20.30	59	61
Taraori basamati	110	90	4	5	21.02	20.12	57	62
Arc 10075	115	95	4	5	23.42	23.25	57	63
Sahabhagi	110	95	4	6	21.97	20.70	58	62
Mami hunger	165	120	4	7	10.87	10.30	75	77
Nua dhusara	115	110	4	5	19.65	19.35	69	72
Nalbora	175	110	6	7	18.37	15.45	71	75
Manipuri black	165	125	4	7	13.87	13.12	73	76
Masuri	95	90	3	5	20.17	16.57	65	69
Pusa basamati	145	115	5	6	19.07	18.40	61	66
Heera	105	95	3	5	26.00	25.12	45	50
Lalat	85	75	3	5	21.52	21.32	54	56
Geetanjali	125	95	3	6	23.95	23.40	52	57
Mornodoinga	115	100	3	6	25.67	25.35	52	55
Swarna	95	80	3	5	25.65	25.47	49	53
CR Dhan 311	105	90	3	5	20.55	20.32	58	61
PB-177	105	95	3	6	21.10	21.02	60	63

RM: raw milled; **PM:** parboiled milled

Table 3: Grain quality analysis of raw milled and parboiled milled of twenty genotypes of rice.

Parameter	Cultivars (C)	Treatment (T)	C X T
Glycemic index	****	****	****
Glycemic load	****	****	NS
Resistant starch	****	****	****
Amylose content	****	****	****

NS: Not significant at $P \leq 0.05$, ****: Significant at $P \leq 0.001$

Table 4: ANOVA table for interaction between treatment (raw brown, parboiled brown, raw milled and parboiled milled) of twenty genotypes of rice.

4.2 Effect of parboiling on Glycemic index, Resistant starch and Glycemic load of rice:

Varietal differences of rice can produce genotype with a diverse range of amylose, in turn, with varying GI values. Further, the processing of rice such as soaking, parboiling, could alter its GI value (Sivakamasundari et al., 2021). Parboiling induced changes in the starch characteristics which can be evaluated by determining the GI, GL and RS of rice. In view of the increased risk of lifestyle diseases, there is higher demand and preference for food and food products having low GI. Therefore millers, traders and consumers strongly look for rice with low GI. Reports reveal that parboiling reduces the GI of rice by almost 30 % when compared to non-parboiled rice of the same variety (Larsen et al., 2000). The *in vitro* GI of non-parboiled and parboiled rice is represented in Table 5. The GI varied significantly ($P < 0.05$, Table 4) among genotypes in RB rice which ranged from 54.53 in Lalat to 67.87 in Sahbhagidhan (Table 5) After parboiling, the GI value was significantly reduced ($P < 0.05$, Table 4) to less than 55 in most of the PB rice genotypes while its value was slightly increased to 55 ± 2 after milling in all the genotypes of PM rice (Table 5) The parboiling of brown and milled rice of almost all cultivars was reported to be significantly ($P < 0.05$, Table 4) lower GI compared to its respective RB and RM treatment Among the different form of rice, brown rice contains more insoluble fibre and various phytonutrients that can reduce starch digestibility which can result in a lower risk of type-II diabetes (Kumar et al., 2018) Brown rice exhibits longer cooking times and lesser gelatinization, in turn slowing down the digestibility of starch in the small intestine (Mir et al., 2015) However, the shelf-life of brown rice is lesser and have poor sensorial attributes than white rice due to which there is a lower preference by consumers (Sivakamasundari et al., 2021) As white rice is nutritionally poor, people from Southern Asia and Western Africa prefer to consume parboiled rice which is considered a method of nutrient fortification and also showing a lower glycemic response (Sivakamasundari et al., 2020; Zohoun et al., 2018)

Given the impact of RS on the glycemic response for rice, its content was estimated in brown rice and processed rice. Parboiled rice (both PB and PM) exhibited increased RS compare to RB and RM rice irrespective of all the genotypes. RS of RB rice was found to range between 0.63 % in Mamihunger to 2.47 % in PB-177 (Fig. 1) and its content was increased after parboiling which is consistent with the report of Sivakamasundari et al., (2020) Parboiling of both brown and milled rice has reported having significantly ($P < 0.05$; Table 4) increased RS in almost all the genotypes Parboiled rice with a higher degree of gelatinization may increase the RS and in turn, reduce the GI. Further, gelatinization and re-crystallization of rice starch during parboiling may also increase its RS content (Sivakamasundari et al., 2020), thus reducing the GI. During parboiling, gelatinized starch after retrogradation form type-III

RS which is slowing starch digestibility (Sivakamasundari et al., 2021) Further, the amylose molecules of starch form a complex with lipid (type-V RS) which is an insoluble film on the starch granules and is highly resistant to digestion (Kumar et al., 2018)

The GL ranged from 16.4 (Lalat) to a maximum of 23 (Sahbhagidhan) in RB rice (Table 5) After parboiling, the GL value was decreased significantly ($P < 0.05$, Table 4) in both PB and PM rice which is attributed to reduced available carbohydrate in all the genotypes after thermal processing Low GL value in Lalat indicated a lesser extent of starch digestibility while the higher GL of other genotypes suggests that the rate and quantum of starch digestion have been comparatively higher in these genotypes (Prasad et al., 2018). The GL varied significantly ($P < 0.05$, Table 4) among the genotypes, which is the result of variation in GI and available carbohydrate. Similarly, the GL was also varied due to the treatment of parboiling in both brown and milled rice. However, the interaction of varieties and treatment showed the non-significant ($P > 0.05$, Table 4) values which may be due to lesser variation in available carbohydrate content. The GL varies mainly due to the GI of the rice cultivar and the available carbohydrate content which may be affected due to different processing conditions (Prasad et al., 2018).

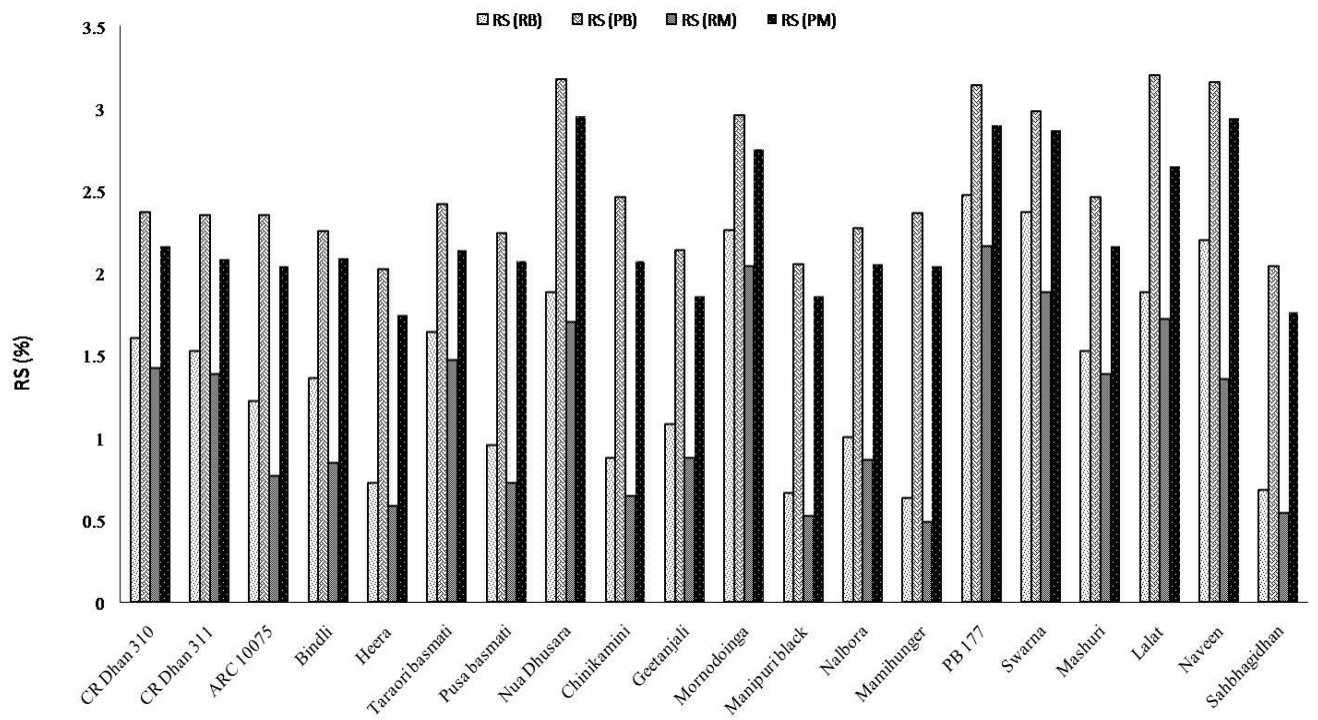


Fig. 1: Resistant starch (RS) of raw brown (RB), raw milled (RM), parboiled brown (PB) and parboiled milled (PM) of twenty rice genotypes.

Rice traits	Genotypes	GI (RB)	GI (PB)	GI (RM)	GI (PM)	GL (RB)	GL(PB)	GL (RM)	GL (PM)
High protein	CR Dhan 310	60.87 ± 0.59	52.87 ± 0.3	61.84 ± 0.88	54.85 ± 0.63	18.98 ± 0.05	16.43 ± 0.20	19.89 ± 0.08	17.29 ± 0.37
	CR Dhan 311	61.32 ± 0.73	53.06 ± 0.91	62.14 ± 0.33	55.18 ± 0.97	19.01 ± 0.20	16.38 ± 0.55	19.97 ± 0.36	17.33 ± 0.57
	ARC 10075	63.45 ± 1.28	53.38 ± 1.08	65.08 ± 0.77	55.19 ± 1.05	19.90 ± 0.44	16.59 ± 0.48	20.93 ± 0.43	17.41 ± 0.53
	Bindli	62.31 ± 0.93	53.27 ± 0.52	63.25 ± 0.94	55.18 ± 0.3	19.78 ± 0.64	16.82 ± 0.60	20.65 ± 0.58	17.70 ± 0.31
	Heera	65.30 ± 0.60	55.04 ± 0.20	66.83 ± 0.94	56.86 ± 0.92	20.73 ± 0.22	17.46 ± 0.64	21.83 ± 0.71	18.24 ± 0.40
Scented	Torari basamati	60.00 ± 0.28	52.78 ± 0.60	61.57 ± 0.51	54.64 ± 0.45	21.08 ± 0.42	18.25 ± 0.13	22.18 ± 0.24	19.16 ± 0.53
	Pusa basamati 1	64.53 ± 1.22	53.86 ± 0.75	65.63 ± 0.54	55.74 ± 1.00	22.01 ± 0.35	18.13 ± 0.33	23.02 ± 0.26	18.98 ± 0.23
	Nuadhusara	59.71 ± 0.66	52.31 ± 1.22	60.84 ± 0.5	54.36 ± 0.67	18.94 ± 0.31	15.92 ± 0.64	19.86 ± 0.26	16.62 ± 0.57
	Chinikamini	63.41 ± 1.09	53.95 ± 0.86	65.26 ± 1.14	55.26 ± 0.67	21.41 ± 0.38	18.12 ± 0.34	22.59 ± 0.59	18.82 ± 0.64
	Geetanjali	63.69 ± 0.67	54.28 ± 1.00	65.08 ± 0.5	56.16 ± 0.59	20.77 ± 0.49	17.52 ± 0.18	21.88 ± 0.48	18.30 ± 0.32
Pigmented	Mornodoiga	58.76 ± 1.16	51.26 ± 0.53	60.04 ± 0.92	53.17 ± 0.38	18.83 ± 0.32	16.05 ± 0.34	19.70 ± 0.61	16.72 ± 0.69
	Manipuri black	66.25 ± 1.22	54.71 ± 0.33	68.14 ± 1.03	56.04 ± 0.91	21.58 ± 0.59	17.75 ± 0.61	22.91 ± 0.25	18.29 ± 0.52
	Nalbora	62.51 ± 1.21	53.86 ± 1.16	64.06 ± 0.59	55.48 ± 0.53	20.77 ± 0.53	17.85 ± 0.50	22.11 ± 0.35	18.63 ± 0.50
	Mamihunger	67.31 ± 0.56	55.08 ± 0.93	68.42 ± 0.66	57.73 ± 1.24	21.11 ± 0.56	17.16 ± 0.36	22.01 ± 0.27	18.21 ± 0.44
	PB- 177	57.90 ± 0.27	52.28 ± 0.82	59.15 ± 0.64	54.05 ± 0.16	18.62 ± 0.16	16.24 ± 0.46	19.56 ± 0.48	16.99 ± 0.19
General	Swarna	60.79 ± 0.43	52.15 ± 0.55	61.3 ± 0.41	54.07 ± 0.97	19.15 ± 0.35	15.82 ± 0.61	19.70 ± 0.6	16.56 ± 0.51
	Mahsuri	61.32 ± 1.15	52.24 ± 0.56	62.75 ± 0.27	54.27 ± 0.42	19.35 ± 0.36	16.49 ± 0.64	20.41 ± 0.30	17.15 ± 0.36
	Lalat	54.53 ± 1.19	50.76 ± 0.67	56.74 ± 0.24	52.58 ± 0.74	16.41 ± 0.75	15.03 ± 0.30	17.64 ± 0.50	15.45 ± 0.52
	Naveen	59.79 ± 1.23	53.47 ± 0.11	61.32 ± 0.70	54.74 ± 1.18	19.73 ± 0.91	17.33 ± 0.53	20.62 ± 0.62	17.90 ± 0.31
	Sahabhagi dhan	67.87 ± 0.56	55.42 ± 0.67	68.28 ± 0.81	57.14 ± 0.37	23.00 ± 0.42	18.59 ± 0.19	23.65 ± 0.64	19.42 ± 0.66

Table 5: Glycemic index (GI) and glycemic load (GL) of raw brown (RB), raw milled (RM), parboiled brown (PB) and parboiled milled (PM) of twenty rice genotypes.

CHAPTER-5
CONCLUSION

CONCLUSION

The present scenario of lifestyle-related disease has a greater impact on health and the development of immunity in human. There is a plethora of research that has indicated the risk of diabetes and increased dietary intake of high carbohydrate food that leads to have an increase in postprandial blood glucose response. However, various processing method in rice has suggested to lower starch hydrolysis index, GI and GL. The present research works suggest that parboiling of rice has a lower GI index and GL with an increase in RS content. Parboiled rice with a higher degree of gelatinization has resulted to have lower GI and higher RS content. Present work will open an area for food technologist to develop various processing method and products of rice which might be beneficial for diabetics in particular and health-conscious people in general.

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