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IMPACTS OF SOAKING TIME AND STEAMING TIME ON PROXIMATE, VITRO-STARCH DIGESTIBILITY AND AMYLOSE CONTENT OF SHORT, MEDIUM AND LONG RICE GRAIN TYPE

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ABSTRACT

This study aimed to evaluate the impacts of soaking time, steaming time and rice grain type (FARO 15 (short rice grain), FARO 60 (medium rice grain) and FARO 62 (long rice grain) on the proximate composition, in-vitro starch digestibility (rapidly digestible starch (RDS), slowly digestible starch (SDS), resistance starch (RS) and glycemic index (GI)), amylose and amylopectin contents of rice using Taguchi design. A Pareto chart was used to identify the most significant process factor. The highest crude protein content (12.14%), ash content (1.06%) and carbohydrate content (83.85%), amylose (25.06%) and GI (67.24%) were obtained in long grain rice while the highest RS (22.46%) and amylopectin (81%) were obtained in medium grain rice. The type of rice grain had the most significant impact on moisture, carbohydrate, ash, RS and GI. In contrast, the interaction of rice grain type and soaking time had the most significant influence on crude protein, fibre and SDS. The interaction of rice grain type and steaming time influences amylose and amylopectin contents. This study provides valuable information for rice processors on the nutritional and starch digestibility of three different classes of rice varieties and their optimum processing conditions.

1. Introduction

Rice (*Oryza sativa* L.) is one of the most consumed staple foods globally, which contributes to the nutrients intake in the diet of humankind (Sanusi *et al.*, 2017). Rice consumers often consume short grain, medium grain or long grain rice as one of the primary sources of carbohydrates and a staple food for almost half of the world's population. The nutrient quality of rice is usually affected by post-harvest handlings, such as parboiling, which involves soaking, steaming and drying (Ayamdoo *et al.*, 2015). Parboiling is a simultaneous hydration and heat treatment executed on paddy rice to improve rice quality. The parboiling process is a crucial hydrothermal process that significantly enhances rice milling quality, cooking characteristics, and nutrient retention (Ejebe *et al.*, 2015; Sanusi and Akinoso, 2020). Parboiling results in alteration of rice, which causes the vitamins and minerals to be transferred from the germ and aleurone into the starchy rice endosperm. These transfigurations, however, cause a reduction in whiteness and give de-husked rice a more pellucid appearance during polishing (Ejebe *et al.*, 2015). The parboiling process includes soaking paddy rice in hot water, steaming to ensure starch gelatinization, and drying before de-husking and milling operations (Onmankhong *et al.*, 2020; Sanusi and Akinoso, 2022). Relevant information on starch digestibility, glycemic index, resistance starch, amylose and amylopectin of rice are important factors influencing proper nutrition and prevention of diseases. According to Nakayama *et al.* (2017), rice with high amylopectin content and glycemic content could increase the risk of diabetes because of the high rate of digestible starch that leads to a rise in blood glucose level within the short term. Resistance starch is also directly proportional to the amylose content (Khatun *et al.,* 2019). This means an increase in amylose content and resistance starch contents resulted in a lower glycemic index. Zafar (2018) stated that resistance starch reduces the postprandial blood glucose level due to its dietary fibre in the gastrointestinal. Several studies have been reported on the influence of parboiling conditions on rice milling quality and nutritional composition. Ayamdoo *et al.* (2015) said that parboiling causes changes in the physical and chemical composition of Jasmine 85 and NERICA 14.

Buggenhout et al. (2013) reported that parboiling could significantly influence rice's milling and physicochemical properties. Ebuehi and Oyewole (2007) examined the influence of parboiling on the physical properties of raw ofada and aroso rice varieties, while Min et al. (2014) examined the effects of soaking and cooking on antioxidant compounds from red, purple and brown genotypes. Paiva *et al.* (2016) reported the effect of polishing and parboiling on the nutritional properties of red and black rice varieties. Sivakamasundari *et al*. (2020) reported the effect of parboiling on the amylose and amylopectin Karaya cultivar and waxy cultivar. Sanusi and Akinoso (2021) studied the impacts of parboiling variables on the energy consumption and quality of brown rice. However, literature is sparse on the impacts of soaking time, steaming time and rice grain type on the proximate composition, in-vitro starch digestibility, amylose and amylopectin contents of rice. The study of the influence of soaking temperature and steaming time during parboiling of different rice varieties on the proximate composition, in-vitro starch digestibility, amylose and amylopectin contents of could provide an avenue to understand the impact processing variables and conditions on the nutritional contents of the rice varieties. It could as well be useful for commercialization purposes based on rice grain type optimum conditions for better nutrient attributes. The rice varieties under consideration in this study are short rice grain, medium rice grain and long rice grain. The selection of rice varieties with superior nutritional content is critical for consumers and producers. This study is expected to provide valuable information to rice producers and consumers on the impact of soaking time, steaming time and rice grain type on the proximate composition, in-vitro starch, amylose and amylopectin contents. Therefore, the objective of this study was to evaluate the impact of soaking time (4 h, 5 h and 6 h), steaming time (30 min, 35 min and 40 min), and rice grain type (FARO 15, FARO 60 and FARO 62 on the proximate composition, in-vitro starch digestibility (Readily digestible starch (RDS), slowly digestible starch (SDS) and resistance starch (RS) and glycemic index (GI), amylose and amylopectin contents of rice.

2. Materials and Methods

2.1. Materials

This study used three varieties of paddy rice; FARO 15 (short rice grain), FARO 60 (medium rice grain) and FARO 62 (long rice grain), which were purchased grain quality laboratory NCRI, Nigeria.

2.2. Experimental design

Taguchi experimental design was used to interact soaking time, steaming time and rice grain type on proximate composition, in-vitro starch digestibility, amylose and amylopectin contents of rice, as shown in Table 1. The experimental design consisted of three independent variables; soaking time (4, 5 and 6 h) and steaming time (30, 35 and 40 min) and rice grain type (FARO 15, FARO 60 and FARO 62). The dependent variables were proximate composition (moisture content, crude protein, crude fat, crude fibre, ash and carbohydrate), in-vitro-starch (Readily digestible starch (RDS), slowly digestible starch (SDS) and resistance starch (RS)), glycemic index (GI), amylose and amylopectin contents of the rice.

Table 1. Taguchi experimental design for the impact of rice type, steaming time and soaking time

Process Factors	Unit	Level 1	Level 2	Level 3
Rice grain type		1	2	3
Soaking Time	h	4	5	6
Steaming Time	min	30	35	40

where; 1 is the FARO 15; 2 is the FARO 60 and 3 is the FARO 62

2.3. Paddy rice processing

The paddy rice of FARO 15, FARO 60 and FARO 62 were cleaned to remove foreign materials using rice cleaner. Rice grain type of 6 kg each was used and steeped in a dual-powered rice parboiler, where water was heated to 80°C. FARO 15 was first introduced and soaked for 4 h, 5 h and 6 h, respectively. After achieving 30% paddy rice moisture content, the paddy rice was steamed at 100°C for 30 min, 35 min and 40 min, respectively. The same procedure was repeated for FARO 60 and FARO 62 based on the Taguchi experimental design. The steamed rice paddies of FARO 15, FARO 60 and FARO 62 were dried to 14% moisture content (wb) using an oscillatory rice dryer. To obtain milled rice, the dried paddy rice of each type was milled using a rice miller (Model MLNJ-15-13, India). The resulting milled rice for each rice grain type under different processing conditions was analyzed for their proximate composition, in-vitro-starch, amylose and amylopectin contents. Pareto chart was used to determine the significant processing parameters (soaking time, steaming time and rice grain type. In the pareto chart a reference line is drawn on the chart to indicate the P=0.05 threshold for statistically significant effect.

2.4. Proximate composition

The proximate composition in terms of the moisture content, crude protein, crude fat, ash and crude fibre were analyzed using AOAC (2016), while the carbohydrate content was determined using the difference method.

2.5. Amylose and amylopectin content

The amylose content of the rice samples was determined by using the method of Al-Rabadi et al. (2009) while amylopectin was determined using equation 1

$$Amylopectin = 100 - (amylose) \qquad (1)$$

2.6. In-vitro starch digestibility

In vitro starch digestibility was determined using a modified Englyst method. 100 mg of dried sample was suspended in 2 mL 0.1M sodium acetate buffer (pH 5.2) and incubated at 37°C for 5 min before the addition of 100 µL of diluted α-amylase and 100 µL of diluted amyloglucosidase. Samples were incubated in a shaking water bath at 37°C for 120 mins. 50 µL aliquots were pipetted into 2 mL micro-centrifuge tubes containing 400 µL of cold ethanol after 20, 60 and 120 min of digestion. The glucose released at each interval was determined using the glucose oxidase / peroxidase method and was converted to the percentage of starch hydrolyzed by multiplying by 0.9. Starch digested at 20 min is defined as rapidly digestible starch (RDS), starch digested between 20 and 120 min is defined as slowly digestible starch (SDS), and starch not digested after 120 min incubation is defined as resistance starch (RS).

2.7. Glycemic index

The glycemic index was calculated from the ratio of the increment area under the curve of the glucose response curve of test food sample containing 50 g of available carbohydrate and the same amount of reference food and expressed as a percentage.

2.8. Statistical analysis

All analysis was carried out in triplicate and the experimental data were reported as mean± standard deviation (SD). The data were subjected to analysis of variance (oneway ANOVA). The significant difference was determined by Duncan’s (significance difference) test $p \leq 0.05$ and Pareto chart was used to determine the most significant factor at p≤0.05.

3. Results and Discussions

3.1. Proximate Composition

Table 2 shows the effect of rice grain type, soaking time and steaming time on the proximate composition. The moisture content ranged between 5.06 and 13.75% crude protein (8.02 and 12.14%), crude fat (0.85 and 1.27%), crude fibre (0.44 and 0.61%), ash content (0.51 and 1.06%) and carbohydrate content (75.02 and 83.85%), respectively. The highest moisture content (13.75%) was observed in FARO 15 while the lowest moisture content (5.06%) was observed in FARO 62. The difference in the moisture content could be traced to the rate at which the rice grain type imbibes water and become moist. In addition, 40 min steaming time used in FARO 62 could also reduce the moisture content because, during long steaming, excess moisture content evaporates to vapour due to reduction from saturation point to a normal level. Thus, the moist starch would be transformed into a gelatinous substance. This finding agreed with Ayamdoo *et al.* (2015) that an increase in steaming duration decreases the moisture content of Nerica-14 and Jasmine-85.

Table 2. Effect of rice grain type, soaking time and steaming time on proximate content (%)

Rice variety	Soaking time (mins)	Steaming time (mins)	Moisture	Crude protein	Crude fat	Crude fibre	Ash	CHO
FARO 15	4	30	13.06±0.01b	8.04±0.00h	1.22±0.00e	0.46±0.01f	0.51±0.00e	76.71±0.00h
FARO 15	5	35	13.75±0.01a	9.16±0.00f	0.95±0.00h	0.52±0.00e	0.60±0.01d	75.02±0.02i
FARO 15	6	40	8.15±0.00c	9.08±0.00g	1.11±0.00a	0.57±0.00d	0.63±0.00c	80.45±0.01e
FARO 60	4	40	6.45±0.00d	10.48±0.00d	0.85±0.00g	0.61±0.00a	1.03±0.01b	80.57±0.02d
FARO 60	5	30	5.86±0.01f	12.07±0.01b	1.30±0.00c	0.52±0.00e	1.02±0.00b	79.23±0.02e
FARO 60	6	35	6.14±0.01e	10.26±0.00f	1.02±0.00f	0.58±0.00c	1.05±0.00a	80.94±0.00e
FARO 62	4	35	5.25±0.00e	8.02±0.01i	1.21±0.00b	0.60±0.00b	1.06±0.00a	83.85±0.01a
FARO 62	5	40	5.06±0.01g	10.52±0.00c	1.27±0.00d	0.43±0.00g	1.06±0.00a	81.65±0.02b
FARO 62	6	30	6.14±0.01eh	12.14±0.01a	1.02±0.01f	0.52±0.00e	1.03±0.00b	79.14±0.02g

Means in a column, within processing condition, not followed by a common letter are significantly different at P < 0.05

The Pareto chart in Figure 1 (a) showed that rice grain type, quadratic effect of rice grain type and interaction of rice grain type and steaming time were the three most significant factors influencing the moisture content. The highest crude protein (12.14%) was observed in FARO 62 while the lowest crude protein content (8.02%) was observed in FARO 62 but under different conditions. FARO 60 was observed to have high crude protein content than FARO 15 regardless of the processing conditions. This could be due to the inherent difference in the rice varieties' protein content and the processing conditions. Kale *et al.* (2015) reported that the protein content of Basmatic rice differs based on soaking duration. Also, Ayamdoo *et al.* (2015) observed differences in the protein content of different rice varieties. The Pareto chart in Figure 1 (b) showed that quadratic effect of rice grain type and interaction between rice grain type and soaking time had the most significant influence on crude protein content. The highest crude fat (1.30%) was observed in FARO 60 while the lowest (0.85%) was also observed in FARO 60 at 4 h soaking time and 40 min steaming time. The low crude fat content could be attributed to the long steaming duration, which causes the oil in the rice embryo to diffuse and dissolve. The Pareto chart in Figure 1 (c) shows that the quadratic effect of steaming time and interaction of rice grain type and soaking time had the most significant influence on crude fat content. Patindol *et al.* (2008) reported an increase in the crude fat content as the parboiling conditions increased, while Ayamdoo *et al.* (2015) reported a difference in the crude fat content of Nerica 14 and Jesmine 85 due to steaming time. The highest crude fibre (0.61%) was recorded in FARO 60. The lowest crude fibre (0.44%) was observed in FARO 62. The Pareto chart in Figure 1 (d) showed that the interaction of rice grain type and soaking time and quadratic effect of rice grain type had the most significant influence on crude fibre content. The low amount of crude fibre observed in this study and the difference in the crude fibre of the rice varieties could be attributed to the low heat generation during the soaking and steaming process, thus do not significantly degrade the fibre within the rice varieties.

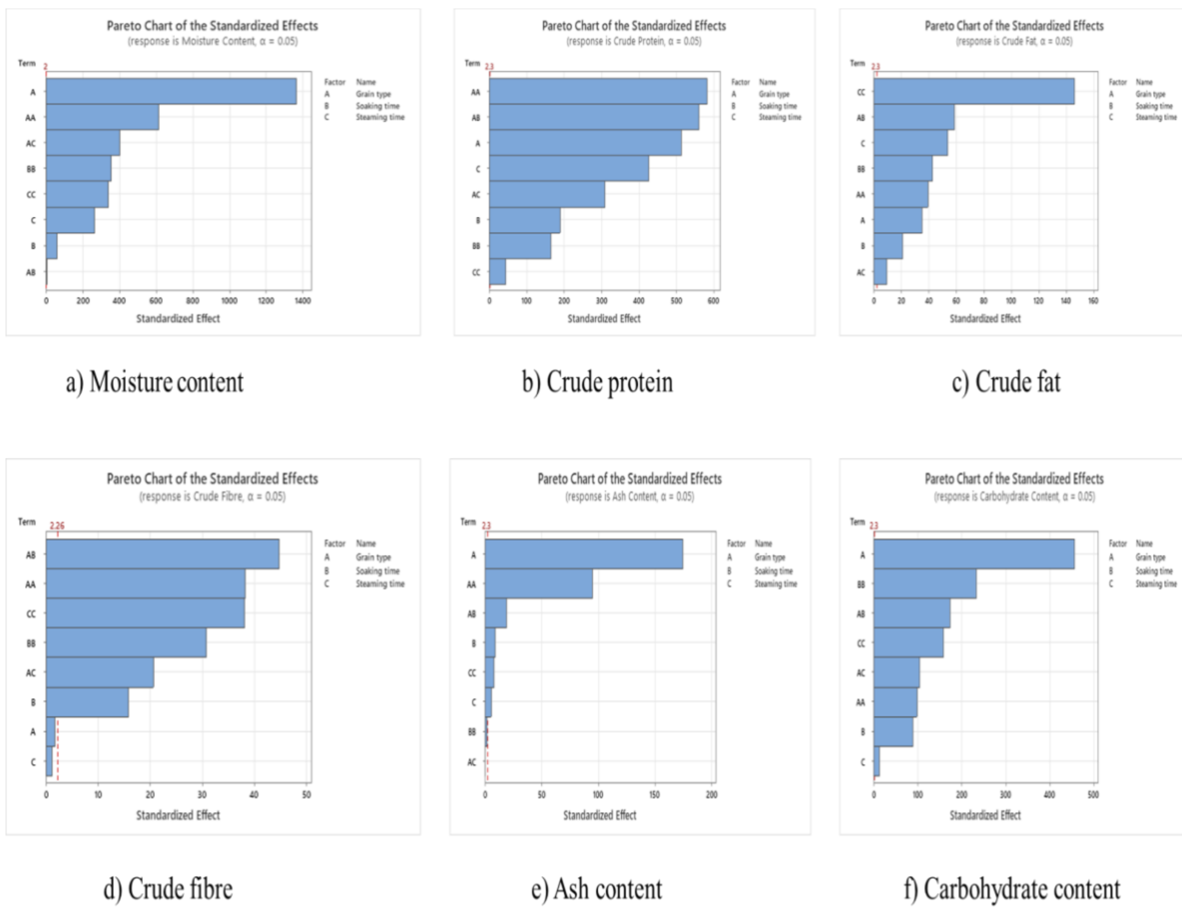


Figure 1. Impact of soaking time, steaming time and rice grain type on proximate composition of rice

In addition, the genetic makeup of the rice varieties may also influence it. This result corroborates with the findings of Kale *et al.* (2015) that crude fibre is low in brown rice and polished rice. The highest ash content (1.06%) was observed in FARO 60 and 62 while the lowest ash content (0.51%) was observed in FARO 15. The Pareto chart in Figure 1 (e) showed that rice grain type and quadratic effect of rice grain type influenced the ash content. The result agrees with Ayamdoo *et al.* (2015) that the rice grain type has significantly affected ash content. Therefore, it can be deduced that the ash content of the medium (FARO 60) and long rice (FARO 62) is more than the short rice (FARO 15). The highest carbohydrate content (83.85%) was observed in FARO 62 while the lowest (75.02%) was observed in FARO 15. The difference in the carbohydrate content could be attributed to the rice grain type and the soaking condition. During soaking, exudation of endosperm starch occurs due to low amylose content that might be present in the variety, causing severe grain deformation that reduces the carbohydrate content. Islam *et al.* (2004) reported similar findings that rice grain type and soaking process influence carbohydrate content. The Pareto chart in Figure 1(f) showed that rice grain type and quadratic effect of soaking time significantly influenced the carbohydrate content.

3.2. Vitro-Starch Digestibility

The digestibility of starch is associated with the proportion of starch that is absorbed in the small intestine, and based on this absorption rate, starch is classified into Rapidly Digestible Starch (RDS), Slowly Digestible Starch (SDS) and Resistant Starch (RS) (Muttagi and Ravindra, 2021). The RDS are rapidly converted into glucose by the body while SDS slowly breaks down. Conversely, the portion of starch or starch products that resist digestion as they pass through the small intestine is referred to as resistance starch (Tsuiki *et al.,* 2016). That is, the body cannot easily digest them and could pass through the digestive system untouched, similar to dietary fiber. The effect of rice grain type, soaking time and steaming time on vitro starch digestibility of rice is shown in Table 3.

Table 3. Effect of rice grain type, soaking time and steaming time on in-vitro starch, amylose and amylopectin contents

Rice Variety	Soaking Time (h)	Steaming Time (mins)	RDS %	SDS %	RS	Glycemic index	Amylose Content %	Amylopectin Content %
FARO 15	4	30	74.85±0.03a	16.92±0.03g	8.23±0.06e	66.24±0.00b	23.36±0.00c	76.64±0.00f
FARO 15	5	35	69.40±0.01d	22.46±0.01a	8.14±0.01e	64.22±0.00c	20.06±0.00f	79.94±0.00c
FARO 15	6	40	71.83±0.00h	21.14±0.00c	7.03±0.00f	62.18±0.00d	24.03±0.00b	75.97±0.00g
FARO 60	4	40	72.92±0.00i	16.90±0.00g	10.18±0.01a	58.66±0..00f	23.05±0.01d	76.95±0.00e
FARO 60	5	30	72.06±0.00e	17.88±0.01f	10.06±0.01a	60.26±0.00e	18.25±0.00h	81.00±0.00a
FARO 60	6	35	69.56±0.00c	20.44±0.00e	10.00±0.00a	58.75±0.70f	20.19±0.00e	79.81±0.00d
FARO 62	4	35	71.59±0.00g	19.73±0.00d	8.67±0.00d	50.41±0.23g	19.35±0.00g	80.65±0.00b
FARO 62	5	40	72.56±0.00f	18.14±0.24e	9.29±0.24c	67.24±0.02a	24.06±0.01b	75.94±0.01g
FARO 62	6	30	72.13±0.00b	18.11±0.00e	9.76±0.00b	52.16±0.00g	25.06±0.07a	78.06±2.40h

Means in a column, within processing condition, not followed by a common letter are significantly different at $P < 0.05$

The RDS, SDS, RS and glycemic index content ranged between 69.40 and 74.85%, 16.92 and 22.46%, 7.03 and 10.18% and 50.41 and 67.24%, respectively. The highest RDS content (74.85%) was observed in FARO 15 while the lowest RDS (69.40%) also was observed in FARO 15 but at different processing conditions. Polesi *et al.* (2017) reported 32.30 to 35.30% of RDS for raw rice and 74.00 to 80.40% for cooked rice of the same variety. However, a relatively lower range of 48.22 to 61.31% of RDS was reported by Muttagi and Ravindra (2021) for cooked traditional rice varieties. The Pareto chart in Figure 2 (a) shows that soaking time and the interaction of rice grain type and soaking time had the most influence on the RDS. The highest SDS (22.46%) was observed in FARO 15 while the lowest SDS (16.90%) was observed in FARO 60. A range of 41.10 to 44.00% of SDS for raw rice and 0.70 to 1.60% for cooked rice of the same variety was reported by Polesi *et al.* (2017). However, a relatively lower range of 4.87 to 10.02% of SDS was reported by Muttagi and Ravindra (2021) for cooked traditional rice varieties. As expected, the three varieties showed higher levels of RDS and lower levels of SDS due to starch gelatinization (Polesi *et al.,* 2017). The Pareto chart in Figure 2 (b) shows that the interaction of rice grain type and soaking time had the most significant influence on SDS. Considering the health benefits of SDS, the result shows that the interaction of rice grain type and soaking time could improve the rice acceptability from the point of view of starch digestibility. The highest RS (10.18%) was observed in FARO 60 while the lowest RS (7.03%) was observed in FARO 15. No significant difference ($p>0.05$) was observed within the same rice variety; however, significant difference ($p<0.05$) was observed among the rice variety. This implies that irrespective of the processing conditions, rice varieties significantly affect the RS of rice. Polesi *et al.* (2017) reported that the starch structures are responsible for RS in rice samples and the rate of hydrolysis by gelatinising the starch makes it more easily available for enzymatic attack.

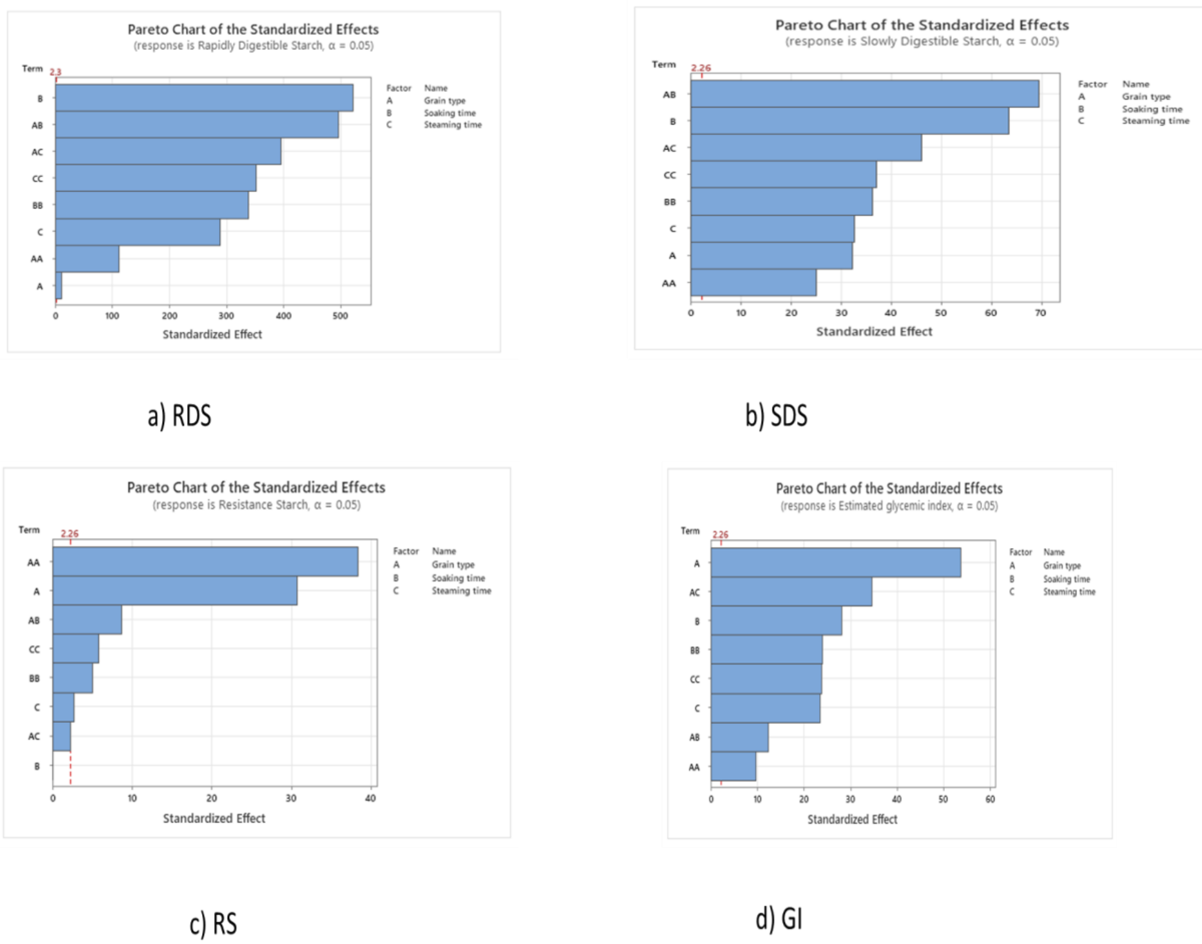
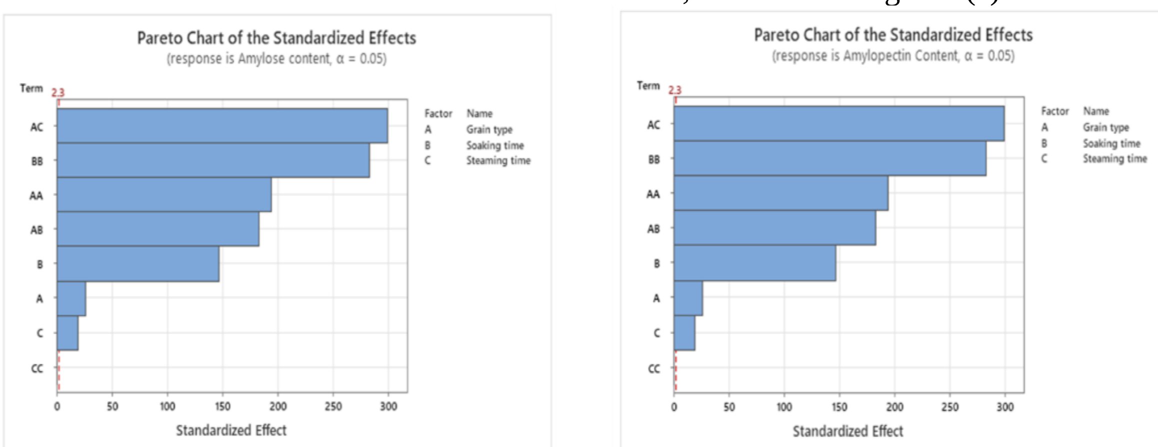


Figure 2. Impact of soaking time, steaming time and rice grain type on in vitro starch digestibility

The Pareto chart in Figure 2 (c) shows that the quadratic effect of rice grain type had the most significant influence on RS. The kinetic component of starch digestion is mainly associated with the so-called glycaemic index (GI), which strongly influences postprandial metabolism. The GI quantifies the postprandial blood glucose response to starchy foods. It is a tool for their characterisation and classification in terms of the physiological response they elicit (Miao *et al.,* 2015; Bello-Perez *et al.,* 2020). The highest GI (67.24%) was observed in FARO 62 while the lowest (50.41%) was also observed in FARO 62 at different processing conditions. The Pareto chart in Figure 2 (d) shows that rice grain type and the interaction of rice grain type and steaming time had the most significant influence on the GI. Tsuiki *et al.* (2016) reported that the difference in structure affects the digested rate of starch. Starch with high amylose content and resistant starch have a lower GI value. GI affects the chemical structure of the starch, amylose and amylopectin, and the level of GI in the body affects the health of the human being. Low GI foods have consistently improved the blood lipid concentration and prevented further diabetic complications (Upadhyaya *et al.,* 2016). Thus, rice grain type with high amylose content and RS could result in a lower GI, which is essential to produce healthier foods and reduce the risk of diabetes and cardiovascular diseases.

3.3. Amylose and Amylopectin content

Starch is a natural polymer, or polysaccharide, meaning that it is a long chain comprising one type of molecule. This molecule is glucose which occurs in two forms: amylose and amylopectin. Amylose is a linear or straight-line polymer, whereas amylopectin forms a branched-chain (Bello-Perez *et al.*, 2020). Table 3 shows the effect of rice variety, soaking time, and steaming time on rice's amylose and amylopectin content. The amylose content ranged from 18.25 to 25.06, and amylopectin content ranged from 75.94% to 81.00%. The highest amylose content (25.06) was observed in FARO 62 at 6 h soaking time, 30 min steaming time, while the lowest amylose (18.25%) was observed in FARO 60 at 5 h soaking time, 30 min steaming time. The difference in values could be attributed to the interaction of rice grain type type and steaming time, which has the highest significance on the amylose content of rice, as shown in Figure 3(a).



a) amylose content

b) Amylopectin content

Figure 3. Impact of soaking time, steaming time and rice grain variety on amylose and amylopectin contents

Muttagi and Ravindra (2021) also reported that rice grain type had a significant influence on the amylose content, affecting the starch digestibility. They also indicated that other factors such as physicochemical properties, granule size, and degree of crystallinity might also substantially affect starch digestibility. The highest amylopectin value (81.00%) was observed in FARO 60 at 5 h soaking time, 30 min steaming time), while the lowest (75.94%) was observed in FARO 62 at 5 h soaking time, 40 min steaming time). The difference in values could be attributed to the interaction of rice grain type and steaming time (AC) which has the highest significance on the amylopectin content of rice, as shown in Figure 3(b). The range of amylose and amylopectin shows that they are normal starches according to Bello-Perez *et al.* (2020).

4. Conclusions

The impacts of soaking time, steaming time and rice grain type on the proximate composition, in-vitro starch digestibility (RDS, SDS, RD and GI), amylose and amylopectin contents of rice were investigated. The results demonstrated significate effects of processing conditions evaluated on the test samples. The type of rice grain had the most significant impact on moisture, carbohydrate, ash, RS and GI. Conversely, the interaction of rice grain type and soaking time had the most crucial influence on crude protein, fibre and SDS. The soaking time and the interaction of rice grain type with soaking time had the most impact on the RDS contents. On the other hand, the interaction of rice grain type with steaming time alone influences the amylose and amylopectin contents. These results will help the Nutritionists select the best processing combinations to provide a more suitable source of starch for chronic disease patients. Also, the food processors could plan adequate diets, especially for school children and elderly ones. Other processing combinations such as cooking methods, soaking temperatures, cooking water uptake, etc can be investigated for further study.

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