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Profiling of physico-chemical and nutritional characteristics of germinated Siddi rice

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Abstract
Rice is a foremost vital staple crop for over half of world's population providing 21.0% of global human per capita energy and 15.0% of per capita protein. The majority of developing nations rely heavily on rice as a basic food. The United Nations recognized the importance of this crop and the declared 2004 as 'International year of Rice'.
Germination is a simple and economic method for improving grain quality and was gaining increased interest due to health benefits of germinated grains. It was inexpensive and effective method for improving the overall nutritional quality of food grains by enhancing their digestibility and total sugars as well as decrease the dry weight and starch content.
In the present study, the physico-chemical and nutritional analysis of the germinated Siddi rice were compared with ungerminated ones. The findings of colour estimation revealed higher L*, b*, E* and lower a* values for germinated Siddi rice resulting lighter and less red coloured grains This signified that germination can profoundly affect the physical parameters of rice grains.
The water activity of raw Siddi rice was 0.65±0.01 and germinated rice was 0.62±0.02. The raw and germinated rice showed moisture content of 12.53±0.18 and 11.57±0.15 ash of 0.78±0.01 and 1.16±0.01, protein of 10.56±0.11 and 11.65±0.14, fat of 1.25±0.09 and 1.10±0.01, crude fiber of 0.32±0.01 and 0.37±0.02, carbohydrates of 73.20±0.33 and 75.61±0.16 g with energy content of 355.70±0.50 and 349.70±0.40 Kcal for 100 g of the samples respectively.
The total sugars, non-reducing sugars contents of germinated rice were higher compared to raw rice by 29.42 and 32.54% respectively whereas reducing sugar, total starch, amylose and amylopectin contents decreased for germinated by 17.50, 11.17, 15.24 and 8.90% respectively.

Keywords: Siddi, germination, physical parameters, geometric characteristics, water activity, cooking quality

Introduction
The cereal grain is the most widely consumed staple food for a great part of the world's human population, mainly in Asia. The crop ranks second worldwide in terms of production and the most important grain for human nutrition and caloric intake because it provides more than one-fifth of the calories consumed by humans worldwide [46].
Rice plays an important role in our national food security, the slogan *"Rice is life"* is more appropriate for India. It refers to means of support for millions of rural households. In Asia, more than 2 billion people depend on rice to meet 80.0% of their energy needs as the grain contains 80.0% carbohydrates, 7-8% protein, 3.0% fat and 3.0% fiber [14].
The indigenous food processing methods like malting /germination increased the nutritional profile of cereals by improving the bioavailability of desired nutrients [11]. It plays an important role in increasing amino acid profile, protein digestibility and vitamins while decreasing anti-nutritional factors than in raw cereals and legumes [52].
The release of enzymes during germination increases the availability of nutrients added flavour during germination. The hydrolysis of complex components into simpler form that can be digested easily and breakdown of lipids into fatty acids to give energy are typically observed during germination [63]. Foods processed from germinated grains possess high oligosaccharides, vitamins, amino acids and antioxidants [54].
The main objective of this study was to compare physico-chemical and nutritional analysis of the germinated Siddi rice variety with ungerminated ones. In view of highly acceptable parameters for 24 hours germination, this time duration was selected as best duration for Siddi rice to further analyse the physico-chemical parameters, functional properties, cooking quality, nutritional quality.

Methodology

The WGL-44 rice is commonly referred to as Siddi was analysed in the present study procured from Krishi Vigyan Kendra, PJTSAU, Wyra, Khammam. The procured paddy sample was stored in jute bags and kept at room temperature till analysis.

The selection of best accepted germination time was based on pre-analysis germination parameters that included vitamin C content, α- amylase activity, milling yield, titratable acidity, pH, total soluble solids content and sensory evaluation carried out at different time intervals of 6, 12, 18, 24, 36, 42, 48 and 54 hours.

The physical properties were analyzed using standard methods like colour [29], 1000 grain weight [47], 1000 grain volume [33], hydration and swelling capacity of thousand grains [67], length-breadth ratio [51], thickness [1], bulk density [59], tapped density [41], true density [21], solid content of uncooked rice [28] and microscopic dimensions [37].

The gravimetric parameters calculated by using standard procedures *viz*., geometric mean dimension [39], aspect ratio [36], compactness ratio [37], surface area [31], volume [38], porosity [62], sphericity [39].

The cooking quality of germinated rice was analyzed using elongation ratio [53], length-breadth ratio [27], volume expansion ratio [53], cooking time [66], water uptake ratio [60], equivalent weight and solid content [28], gruel solid loss [27], alkali degradation [13], gelatinization temperature [32] and microscopic structure of rice starch granules [24].

The functional parameters analyzed were water activity by [2], water absorption index and water solubility index [4], oil retention capacity [12], hydrophilic-lipophilic index [42], foaming capacity [35] and emulsion activity [22].

The chemical and nutritional properties of rice will be analyzed by standard procedures *viz*., moisture [8], ash [9], protein [10], fat [7], crude fiber [6], carbohydrate and energy [5], total sugars, reducing sugars and non-reducing sugar [57], total starch [58], amylose and amylopectin content[68].

All the results were statistically analyzed to test the significance of the outcomes using mean, standard deviation, standard error of mean, CD and percentage CV [56].

Results and Discussion

Cereals undergo significant biochemical and physico-chemical changes during germination. The development and synthesis of hydrolytic enzymes, enhanced protein and carbohydrate digestibility, decreased flatulence brought on by oligosaccharides and denaturing of amylase inhibitors were among the crucial factors, improving the nutritional quality of rice overall [23].

The chemical composition, nutritional value and acceptability traits of products intended for human consumption were significantly influenced by grain germination [17]. It has been claimed that germinated flour from cereals has superior nutritional qualities over non germinated cereal flour and the supplementary foods prepared using germinated flours have low viscosity and high nutrient density that were suitable for weaning infants in developing nations [3].

Physical parameters of germinated Siddi rice

The designing appropriate processing equipment was based on physical and aerodynamic characteristics of agricultural produce to improve the yield [26]. The rice's quality was assessed by considering its size, shape, appearance and cooking characteristics [16].

The physical parameters like colour, 1000 grain weight, 1000 grain volume, hydration and swelling capacity of thousand grain, length/breadth ratio, thickness, bulk density, tapped density, true density as well as solid content of uncooked grains were statistically analysed and presented in Tables 1 and 2.

Colour analysis of germinated rice

Colour scores of RSV and test sample were presented as L*, a*, b* and ΔE values and analysed using Munsell colour charts. The most crucial aspect of any food grain's acceptability is its colour that can be affected by its chemical, biochemical, microbiological and physical changes that take place during development, maturation, post-harvest handling and processing [64].

The L*, a*, and b* units were commonly used in food research studies to establish the uniform distribution of colours since they are remarkably comparable to how human eye perceived it. The colour of foods was crucial as it has a direct affects on the visual appeal of the final product to which they were added [48].

Table 1: Colour analysis of raw and germinated rice

Sample	L*	a*	b*	ΔE
RSV	82.06^{c}±0.10	29.08^{b} ±0.03	13.10^{a}±0.32	28.04^{b}±0.13
TSV	86.32^{d}±0.01	28.18^{a}±0.04	14.09^{b}±0.19	29.67^{c}±0.20
Grand mean	84.19	28.63	13.59	28.85
SE of Mean	0.28	0.09	0.27	0.37
CD	0.27	0.13	1.02	0.65
% CV	0.15	0.12	3.34	0.99

Note:
Values are expressed as mean ± standard deviation of three determinations.
Means within the same column followed by a common letter do not significantly differ at $p \leq 0.05$.
RSV: Raw Siddi rice TSV: Test Siddi rice at 24 hours germination

The L*, b* and ΔE values were best for TSV with 86.32±0.01, 14.09±0.19 and 29.67±0.20 respectively and then RSV with 82.06±0.10, 13.10±0.32 and 28.04±0.13 respectively indicating lighter and yellowness for TSV. The a* value of RSV was higher than TSV indicating red colored RSV flour. There was a statistically significant difference at $p \leq 0.05$ for all colour values.

Table 2: Physical properties of raw and germinated rice

Sample	1000 Grain weight (g)	1000 Grain volume (ml)	Hydration capacity (g)	Swelling capacity (ml)	Length / Breadth uncooked	Thickness (mm)	Bulk density (g/ml)	Tapped density (g/ml)	True density (g/ml)	Solid content - uncooked%
RSV	10.57^b±0.22	8.85^c ±0.20	1.34^b ±0.01	2.30^a±0.05	2.83^a±0.02	1.52^a ±0.00	0.78^a ±0.00	0.86^a ±0.01	2.48^c ±0.05	92.13^a±0.01
TSV	10.03^a±0.00	7.80^b ±0.15	1.84^c ±0.04	2.60^b ±0.11	2.75^a ±0.07	1.52^a ±0.00	0.75^a±0.00	0.80^a ±0.01	2.22^b ±0.01	93.74^b±0.58
Grand mean	10.30	8.32	1.60	2.45	2.80	1.52	0.76	0.84	2.35	92.93
SE of Mean	0.15	0.26	0.11	0.08	0.03	0.00	0.00	0.01	0.06	0.44
CD	0.62	0.70	0.13	0.35	0.21	0.04	0.01	0.06	0.16	1.61
% CV	2.70	3.72	3.66	6.45	3.41	1.25	1.06	3.43	3.10	0.76

Note: Values are expressed as mean ± standard deviation of three determinations.
Means within the same column followed by a common letter do not significantly differ at $p \leq 0.05$.
RSV: Raw Siddi rice TSV: Test Siddi rice at 24 hours germination

The 1000 grains weight of RSV was 10.57±0.22 g and TSV was 10.03±0.00 g, 1000 grains volume of RSV was 8.85±0.20 ml and TSV was 7.8±0.15 ml. The decreased volume of TSV than RSV was due to drying of grains after germination, Germination resulted in increased hydration and swelling capacities of RSV with 1.34±0.01 g and 2.30±0.05 ml respectively to TSV with 1.84±0.04 g and 2.60±0.11 ml respectively for thousand grains. The percentage increase in hydration and swelling capacity of TSV were 37.31 and 13.04% respectively.

The length-breadth ratio of uncooked rice for RSV was 2.83±0.02 and TSV was 2.75±0.07 with grand mean ± SE of 2.80±0.03. The decrease L/B ratio of TSV might be due to adequate drying of germinated grains before milling and thickness of both RSV and TSV were same with 1.52±0.00 and statistically no significant difference at $p \leq 0.05$ was observed between them.

Bulk density governed the storage capacity and transportation systems, the product's packaging needs and weight of the grains. Additionally, it described the behavior of product in dry mixes [43].

The bulk density of RSV was maximum with 0.78±0.00 g/ml while TSV was minimum with 0.75±0.00 g/ml might be due to loss of kernel shape and less L/B ratio, the tapped density of RSV was 0.86±0.01 g/ml and for TSV 0.81±0.01 g/ml and true or kernel density of RSV was 2.48±0.05 and TSV 2.22±0.01 g/ml. The solid content was the total solids present in foods after removing all moisture content. The solid content of uncooked TSV with 93.74±0.58% which was slightly higher than RSV with 92.13±0.01%.

The microscopic dimensional analysis of rice included length, breadth, area and perimeter was carried out using stereo zoom microscope and was presented in Table 3. The length and breadth of RSV were 5.40±0.08 mm and 1.81±0.01 mm respectively whereas for TSV were 5.14±0.09 mm and 1.72±0.04 mm respectively. The area of RSV was 7.83±0.10 mm^2 and for TSV was 7.48±0.14 mm^2. The perimeter of RSV was 12.26±0.14 mm and for TSV was 11.89±0.11 mm. The results were in tune with observations of [25] with the length for the kernels ranging from 5.90 to 7.30 mm and ranged 1.7–1.8 mm respectively.

Table 3: Dimensional parameters of rice

Sample	Length (mm)	Breadth (mm)	Area (mm^2)	Perimeter (mm)
RSV	5.40^a±0.08	1.81^a±0.01	7.83^b±0.10	12.26^c±0.14
TSV	5.14^a±0.09	1.72^a±0.04	7.48^b±0.14	11.89^b±0.11
Grand mean	5.27	1.77	7.65	12.07
SE of mean	0.08	0.02	0.11	0.11
CD	0.35	0.12	0.49	0.49
% CV	2.96	3.16	2.82	1.81

Note: Values are expressed as mean ± standard deviation of ten determinations.
Means within the same column followed by a common letter do not significantly differ at $p \leq 0.05$.
RSV: Raw Siddi rice TSV: Test Siddi rice at 24 hours germination

Table 4: Gravimetric properties of raw and germinated rice

Sample	D_e (mm)	R	Ø	S (mm^2)	R_s	V(mm^3)	ε (%)
RSV	2.70^b±0.01	32.46^a±0.05	34.28^b±0.01	18.96^b±0.07	1.52^a±0.01	0.88^b±0.06	0.47^a±0.00
TSV	2.62^a±0.01	34.51^b±0.08	32.46^a±0.02	17.69^a±0.02	1.61^b±0.02	0.79^a±0.09	0.52^b±0.00
Grand mean	2.66	33.48	33.37	18.32	1.56	0.83	0.65
SE of Mean	0.03	0.56	0.03	0.06	0.02	0.13	0.00
CD	0.04	24.99	0.07	2.58	0.07	0.32	0.02
% CV	0.46	3.67	1.25	1.97	2.08	2.19	1.38

Note: Values are expressed as mean ± standard deviation of three determinations.
Means within the same column followed by a common letter do not significantly differ at
RSV: Raw Siddi rice TSV: Test Siddi rice D_e: Geometric mean dimension
R: Aspect ratio Ø: Sphericity R_s: Compactness ratio
S: Surface ratio V: Volume ε: Porosity
$p \leq 0.05$.

Cooking quality of germinated rice

Although proteins, lipids and other components of the cell wall played significant role, the quality and starch content, particularly amylose concentration in food grains had a significant impact on their cooking properties [19].

The cooking quality of rice was characterized by elongation ratio, length-breadth ratio of cooked grains, volume expansion ratio, cooking time, water uptake ratio, gruel solid loss, equivalent weight and solid content of cooked grains, alkali degradation and gelatinization temperature as tabulated in Table 5.

The RSV has higher length wise elongation ratio on cooking with 1.62±0.01 than TSV with 1.36±0.00. The length-breadth ratio of cooked rice RSV was 2.83±0.02 and TSV was 3.19±0.03. The length to breadth ratio of RSV remained similar with the uncooked rice while it was enhanced for TSV indicating that during germination the breakdown of complex starches might have influenced the grain dimensions.

The volume expansion ratio for RSV was 3.82±0.03 and TSV was 2.62±0.01 with a grand mean ± SE of 3.22±0.05. Cooking time was the amount of time required for the opaque part of the rice grain to totally disappear during cooking [30]. The length of time the grains were cooked for also greatly influenced how soft and sticky they can be.

Table 5: Cooking characteristics of raw and germinated rice

Sample	ER	LB (C)	VE	CT	WUR	GSL	EW (C)	SC	AD	GD
RSV	1.62^b±0.01	2.83^a±0.02	3.82^b±0.03	12.30^c±0.42	3.56^b±0.02	10.74^b±0.01	269.6^d±0.50	83.33^d±0.58	5.90^a±0.05	56.33^e±0.40
TSV	1.36^a±0.00	3.19^b±0.03	2.62^a±0.01	10.30^b±0.38	2.81^a±0.02	14.13^a±0.00	250.7^c±0.45	63.49^e±0.31	6.30^b±0.05	52.33^d±0.40
Grand Mean	1.49	3.01	3.22	11.30	3.18	12.43	260.15	73.41	6.10	54.33
SE of mean	0.02	0.06	0.05	0.57	0.19	0.08	4.24	4.44	0.09	1.17
CD	0.03	0.02	0.03	2.26	0.05	0.03	2.72	1.83	0.22	4.71
% CV	1.31	0.42	0.35	10.00	0.53	0.14	0.46	1.10	1.63	3.83

Note: Values are expressed as mean ± standard deviation of three determinations.
Means within the same column followed by a common letter do not significantly differ at $p \leq 0.05$.

RSV: Raw Siddi rice	TSV: Test Siddi rice at 24 hours of germination	ER: Elongation ratio
L/B (C): Length-breadth ratio of cooked rice	VE: Volume expansion	CT: Cooking time
WUR: Water uptake ratio	GSL: Gruel solid loss	EW (C): Equivalent weight of cooked rice
AD: Alkali degradation	GT: Gelatinization temperature	

The cooking time of RSV was 12.30±0.42 min and TSV was 10.30± 0.38 min. The water uptake ratio of RSV was 3.56±0.02 which was higher than TSV with 2.81±0.02. The gruel solid loss of RSV was 10.74±0.01% and TSV was 14.13±0.00%. The equivalent weight of cooked rice for RSV was 269.6±0.50 g/100g and TSV was 250.7±0.45 g/100g. The solid content of equivalent weight of cooked rice for RSV was 83.33±0.58 g and TSV was 63.49±0.31 g. The TSV had less solid content than RSV due to higher gruel solid loss percentage.

The gelatinization temperature of amylose was commonly determined using alkali degradation as a method. The higher the alkali degradation, the lesser was gelatinization temperature [70]. The alkali reaction score for RSV was 5.90±0.05 and for TSV was 6.30±0.05 and statistically significant difference at $p \leq 0.05$ between the samples was observed. The higher alkali degradation for TSV indicated lower gelatinization temperature due to breakdown of starches and easy to cook than RSV.

In the present study, gelatinization temperature of RSV was 56.33±0.40 ^{0}C and TSV was 52.33±0.40 ^{0}C showing statistically significant difference at $p \leq 0.05$ between them.

Microscopic structure of rice starches

The extent of change that starches undergoes during gelatinization and retrogradation were major determinants of their functional properties for food processing during digestion and in industrial applications. These characteristics determined the quality, acceptability, nutritional value and shelf life of finished foods [65]. The native, pregelatinised, gelatinised and retrograded starches of rice for RSV and TSV were visualised under a Lawrence and Mayo binocular microscope to interpret their structural changes after hydrothermal treatments as depicted in Plate 1.

The Plates 1.1 and 1.2 depicted the structure of native RSV and TSV starches with clearly demarcated granules in a semi crystalline and amorphous form. In comparison to non-germinated rice, germinated rice produced a significant number of swollen granules with greater compactness. Both RSV and TSV starch granules were moist, swollen to a greater extent and no longer intact when the native starches were hydrothermally treated and pregelatinized as shown in Plates 1.3 and 1.4.

Prolonged hydrothermal treatment for further starch gelatinization caused the remaining hydrogen bonds to break down leading to loss of birefringence, solubilization of starches and transformation into viscous paste as depicted in Plates 1.5 and 1.6.

When RSV and TSV gelatinized starches were completely cooled, the disintegrated starch chains were able to reorganise into partially ordered structures that were different from native granules as depicted in Plates 1.7 and 1.8 and considered as retrograded starches.

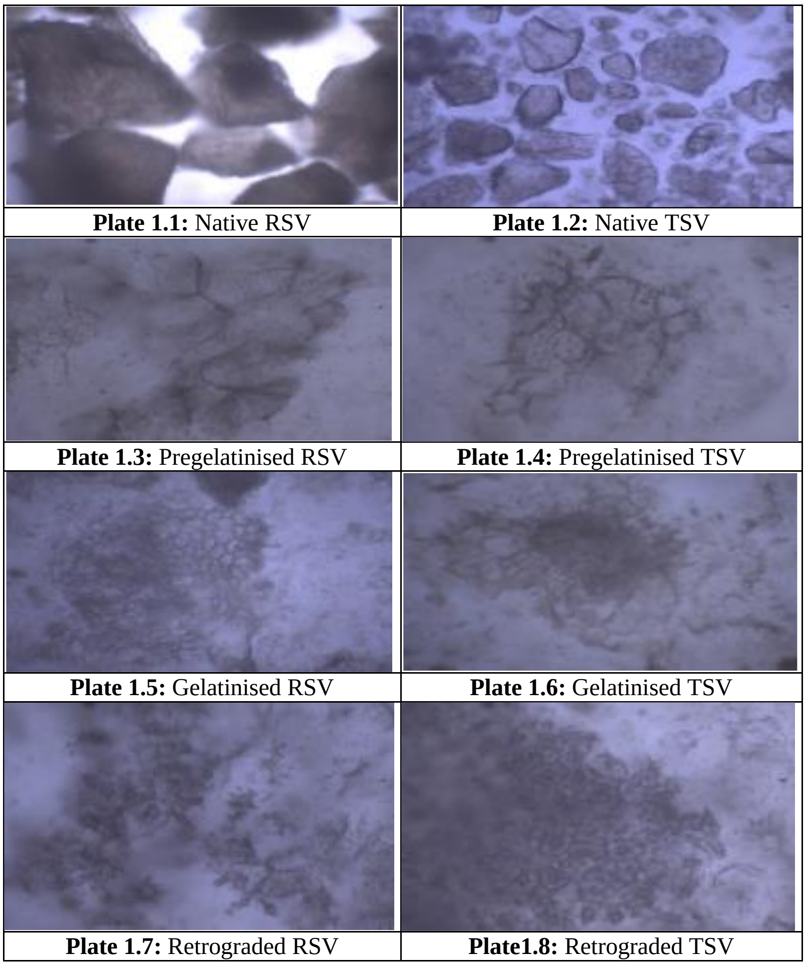

Plate 1.1: Native RSV | **Plate 1.2:** Native TSV
Plate 1.3: Pregelatinised RSV | **Plate 1.4:** Pregelatinised TSV
Plate 1.5: Gelatinised RSV | **Plate 1.6:** Gelatinised TSV
Plate 1.7: Retrograded RSV | **Plate1.8:** Retrograded TSV

Note: RSV: Raw Siddi rice; TSV: Test Siddi rice

Plate 1: Microscopic structures of rice and germinated rice starches

Retrogradation of starches was frequently thought to have negative effect on foods and was a significant cause of the staling of breads and other starch-rich foods causing decreased shelf life and consumer acceptance [15]. However, due to intended change of structural, mechanical and sensory properties, it was beneficial in specific applications the production of breakfast cereals, parboiled rice and dehydrated mashed potatoes [34].

Functional properties of germinated rice

Functional properties are the physicochemical characteristics that showed how different food components interacted and are crucial for various industrial processes and product formulations. They included the interaction between composition, structure, spatial organisation and biophysical characteristics of molecules in relation to the environment and conditions with which they were related and assessed. The use of grain flours in food formulations was dependent on flour functionality [55].

The functional properties of rice included water absorption index, water solubility index, oil retention capacity, hydrophilic-lipophilic index, foaming capacity, emulsion activity and water activity as presented in Table 6.

Table 6: Functional properties of raw and germinated rice

Sample	a_w	WAI (%)	WSI (%)	ORC (%)	HLI	FC (%)	EA (%)
RSV	0.65^{b}±0.01	189.60^{d}±0.40	0.94^{a}±0.00	230.40^{d}±0.20	0.82^{a}±0.00	12.25^{b}±0.55	9.64^{c}±0.45
TSV	0.62^{a}±0.02	198.10^{e}±0.20	1.02^{b}±0.05	192.40^{c}±0.40	1.02^{b}±0.00	14.81^{c}±0.26	12.06^{d}±0.13
Grand Mean	0.63	193.80	0.98	211.40	0.92	13.53	10.85
SE of mean	0.02	2.11	0.17	1.02	0.04	1.05	0.58
CD	0.04	5.70	0.14	4.91	0.01	1. 68	1.30
% CV	2.99	1.29	11.56	1.02	0.06	4.24	5.31

Note: Values are expressed as mean ± standard deviation of three determinations.
Means within the same column followed by a common letter do not significantly differ at $p \leq 0.05$.

RSV: Raw Siddi rice	TSV: Test Siddi rice after germination
a_w: Water activity	WAI: Water absorption index
WSI: Water solubility index	ORC: Oil retention capacity
HLI: Hydrophilic-lipophilic index	FC: Foaming capacity
EA: Emulsion activity	

The a_w for both the samples was analysed at around 20°C with a_w for RSV was 0.65±0.01 and TSV was 0.62±0.02. Various research studies showed that a_w and not moisture content was responsible for processing and keeping qualities of food products [69]. Measuring moisture content was far more feasible and affordable than measuring a_w. Water activity can provide a clear image of a product's shelf stability [50].

The WAI of RSV was 189.6±0.40% and TSV was 198.1±0.20% and The WSI of RSV was 0.94±0.00% and TSV was 1.02±0.05% and statistically significant difference at $p \leq 0.05$ was observed.

ORC was a function of fat binding with non-polar side chains of protein influencing the quantity of hydrophobic sites and protein-lipid-carbohydrate interactions [49]. The ORC of RSV was 230.40±0.20% and TSV was 192.40±0.40%. There was statistically significant difference ($p \leq 0.05$) between the samples.

The HLI of RSV was 0.82±0.00 and for TSV was 1.02±0.00. The FC of RSV was 12.25±0.55% and TSV was 14.81±0.26%. Emulsion activity (EA) was a reflection of proteins' capability to produce emulsions and was correlated with protein's ability to absorb oil and water in an emulsion [18]. The EA of RSV was 9.64±0.45% and TSV was 12.06±0.13%.

Nutritional analysis of germinated Siddi rice

The nutritional parameters help in understanding the nutrient changes that takes place in grains by germination. The proximates, total and reducing sugars along with total starch and amylose were analyzed with calculation of carbohydrates, energy, non-reducing sugars and amylopectin content for the best accepted germinated rice as test sample in comparison to raw grains as control.

Proximates

The estimation of proximates included moisture, ash, protein, fat and crude fiber with calculation of carbohydrates and energy content for 100 g sample and the mean scores of analyses were tabulated in Table 7.

Table 7: Proximate composition of raw and germinated rice

Sample	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Crude fiber (%)	Carbohydrate (%)	Energy (Kcal / 100 g)
RSV	12.53^c±0.18	0.78^a±0.01	10.56^a±0.11	1.25^b±0.09	0.32^a±0.01	75.6^d±0.16	355.70^e±0.50
TSV	11.57^b±0.15	1.16^b±0.01	11.65^b±0.14	1.10^a±0.01	0.37^b±0.02	73.20^c±0.33	349.70^d±0.40
Grand Mean	12.05	0.97	11.11	1.18	0.34	74.40	352.72
SE of mean	0.23	0.08	0.25	0.05	0.01	0.56	1.38
CD	0.63	0.06	0.51	0.26	0.03	1.01	1.87
% CV	2.32	3.12	2.05	9.98	4.24	0.60	0.23

Note: Values are expressed as mean ± standard deviation of three determinations.
Means within the same column followed by a common letter do not significantly differ at $p \leq 0.05$.
RSV: Raw Siddi rice; TSV: Test Siddi rice at 24 hours of germination

The moisture content of RSV was 12.53±0.18% and TSV was 11.57±0.15%. The ash content of RSV was 0.78±0.01% and for TSV was 1.16±0.01% and there was significant difference between the samples ($p \leq 0.01$) was observed.

Germination increased the amount of ash content in grains because activated enzymes broke bonds between minerals, protein and other components thereby increasing the bioavailability of minerals [20][45]. The hydrolytic enzymes may have increased the ash content throughout the germination phase rather than accumulation of total soluble solids. Therefore, regardless of the rice variety, it was indicative that the mineral concentration in GBR is higher than in raw rice.

The protein content of RSV was 10.56±0.11% and TSV was 11.65±0.14%. The fat content of RSV was 1.25±0.09% and TSV was 1.10±0.01%. Crude fiber was the residue left over after vigorous treatment of food sources with acid and alkaline agents. The crude fiber of RSV was 0.32±0.01% and TSV was 0.37±0.02%.

The carbohydrate content of RSV was 73.20±0.33% and TSV was 75.61±0.16%. The energy content of RSV was 355.70±0.50 Kcal/100 g and TSV was 349.70±0.40 Kcal/100g.

Total sugars of germinated Siddi rice

The total and reducing sugars were analyzed from which the non-reducing sugars were calculated as given in Table 8.

The total sugar content of RSV was 15.40±0.26 and TSV was 19.93±0.35% with a grand mean ± SE of 17.67±0.76. The reducing sugar content of RSV was 1.20±0.11 and TSV was 0.99±0.00% with a grand mean ± SE of 1.54±0.10. The non-reducing sugar content of RSV was 14.29±0.28 and TSV was 18.94±0.35% and there was significant difference at $p \leq 0.05$ between the samples was observed.

Total starch content of germinated Siddi rice

The total starch and amylose content were analyzed from which amylopectin content was calculated. The total starch content of RSV was 69.51±0.31 and for TSV was 61.74±0.42% with grand mean ± SE of 65.62±1.00. The amylose content of RSV was 28.20±0.06 and TSV was 23.90±0.80 with grand mean ± SE of 26.05±0.91%. The amylopectin content of RSV was 41.54±0.47 and TSV was 37.84±0.22% with grand mean ± SE of 39.69±1.60 with statistically significant difference at $p \leq 0.05$ between the samples.

Table 8: Total sugars and starch composition of rice

Sample	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)	Total starch (%)	Amylose (%)	Amylopectin (%)
RSV	15.40^b±0.26	1.20^b±0.11	14.29^b±0.28	69.51^d±0.31	28.20^b±0.06	41.54^d±0.47
TSV	19.93^c±0.35	0.99^a±0.00	18.94^c±0.35	61.74^c±0.42	23.90^a±0.80	37.84^c±0.22
Grand mean	17.66	1.54	16.62	65.62	26.05	39.69
SE of mean	0.76	0.10	0.68	1.00	0.91	1.60
CD	1.76	0.21	1.80	4.07	2.03	2.84
% CV	4.77	7.66	5.24	3.63	3.79	4.85

Note: Values are expressed as mean ± standard deviation of three determinations.
Means within the same column followed by a common letter do not significantly differ at $p \leq 0.05$.
RSV: Raw Siddi rice TSV: Test Siddi rice at 24 hours of germination

Conclusion

The present study concluded that the germination altered the physical, microscopic dimensions of rice, geometric parameters, cooking, functional and nutritional properties of rice. The test Siddi rice at 24 hours of germination (TSV) has higher hydration and swelling capacities than raw Siddi variety (RSV) due to the presence of starch fractions that swell more easily as a result of starch hydrolysis since there is more α-amylase activity in TSV. The decrease L/B ratio of TSV might be due to adequate drying of germinated grains before milling.

The solid content of uncooked TSV with 93.74±0.58% which was slightly higher than RSV with 92.13±0.01% probably due to loss of moisture content during drying of germinated rice before milling. The length, breadth, area and perimeter of TSV decreased slightly by 4.81, 4.97, 4.47 and 3.01% respectively than RSV.

Volume expansion of TSV was lesser than RSV by 31.41%. In the present study, RSV had high bulk density than TSV and hence more water uptake ratio was observed. TSV had more gruel solid loss than RSV due to saccharification of complex carbohydrates to simpler ones that easily leached out of kernels into gruel making it suitable for developing easily digestible weaning and instant mixes.

Germination caused an increase in protein influencing the protein's surface-active characteristics and increasing the foaming capacity. TSV had higher carbohydrate content than RSV because it included less moisture and fat content.

The total starch content of RSV was higher than TSV due to the action of different hydrolytic enzymes that cause starch degradation to simpler molecules. The total sugars, non-reducing sugars contents of germinated rice were higher compared to raw ones whereas reducing sugar, total starch, amylose and amylopectin contents decreased for TSV.

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