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Narendra Pangi
Centre of Excellence for Grain Sciences, National Institute of Food Technology, Entrepreneurship and Management, (NIFTEM - T), Thanjavur, Tamil Nadu, India

Nirmal Thirunavookarasu
Centre of Excellence for Grain Sciences, National Institute of Food Technology, Entrepreneurship and Management, (NIFTEM - T), Thanjavur, Tamil Nadu, India

Dr. KA Athmaselvi
Associate Professor and Head, National Institute of Food Technology, Entrepreneurship and Management, (NIFTEM - T), Thanjavur, Tamil Nadu, India

Corresponding Author:
Dr. KA Athmaselvi
Associate Professor and Head, National Institute of Food Technology, Entrepreneurship and Management, (NIFTEM - T), Thanjavur, Tamil Nadu, India

Effect of soaking and steaming duration on the milling, cooking and textural characteristics of black rice (Karuppu Kavuni)

Narendra Pangi, Nirmal Thirunavookarasu and Dr. KA Athmaselvi

Abstract
Among the traditional paddy varieties Karuppu Kavuni is a major traditional black rice variety which is cultivated and consumed in Tamil Nadu region. This rice possesses high nutritive values and antioxidant properties. The Karuppu Kavuni rice was soaked at room temperature for different time duration and they were steamed for 15 and 20 minutes to study the impact of room temperature soaking and steaming on paddy milling. The hardness values of the milled Karuppu Kavuni rice kernels increased linearly with an increase in soaking and steaming time. The obtained results indicate that the soaking beyond 24 hours had negligible influence on the cooking characteristics of Karuppu Kavuni rice. Similarly, the different treatments had no influence on the aroma and taste of the rice kernels after cooking. Further, the different treatments increased the springiness, cohesiveness, gumminess, chewiness and resilience of the cooked Karuppu Kavuni rice.

Keywords: Cooking characteristics, Karuppu Kavuni, Milling characteristics, Soaking, Steaming, Texture characteristics

1. Introduction
Rice (*Oryza sativa* L.) is a major food crop belonging to the family Poaceae. It is a major staple crop consumed by more than half of the world's population (Zahra, Hafeez, Nawaz, & Farooq, 2022) [19]. It is an important crop which is produced in higher amounts as a food crop in the world next to wheat. Asian countries altogether produce and consume nearly 90% of the world's total rice production (Miah, Haque, Douglass, & Clarke, 2002) [14]. Rice is cultivated around the globe in more than one hundred countries along the 45°S to 53°N latitudes regions (Chang, 2003) [6]. The major traditional varieties of rice cultivated in the state of Tamilnadu includes Thanga Samba, Atthur Kichali, Karuppu kavuni, Samba Mappillai, Samba Iluppaipoo, Ganda Sali, Samba Anai komban, Kala namak, Chinnar etc (Karpagalakshmi & Brindha, 2021) [11]. The increasing global population has led to the increase in demand for the modern rice grains which substantially led to the decline in consumption of the traditional rice varieties. However, the consumer current shift in the market scenario of healthy and nutritious foods has increased the need for traditional rice varieties in the market (Ashokkumar *et al*., 2020) [2]. Other than conventional white rice there are pigmented or coloured rice varieties which possess higher amount of antioxidants and nutritive values like yellow rice, brown rice, black rice or red rice,.

A variety of the rice species which has a black pericarp due to its higher anthocyanin and antioxidant content is termed as black rice. It is also referred as Purple rice, imperial rice, paradise rice, forbidden rice, king's rice and valuable rice. Owing to its nutritional benefits and anti-carcinogenic benefits it was considered to increase the life span of the consumers hence therefore it was termed as long-life rice (Kumari Shivani, 2020) [12]. Among the different black rice varieties Karuppu Kavuni cultivated in Tamil Nadu, is well known for its nutritional and antioxidant properties. They are brown-black in colour and found to possess lower amount of fat and soluble sugars. They also contain high protein content and phenolics, which results in darker colour of the grain (Hemamalini, Umamaheswari, Lavany, & Reddy, 2018) [9]. The higher the phenolics present in the pericarp, colour of the Karuppu Kavuni rice darkens. The amount of phenolics present in Karuppu Kavuni is directly proportional to the darker colour of the rice; highly dark rice kernels indicate the higher phenolic content.

The numerous health benefits and sensory properties of the black rice had favoured the consumption and growth of black rice among the other pigmented rice varieties in the current world scenario (Ito & Lacerda, 2019) [10].

Processing of paddy involves a hydrothermal process termed as parboiling where three different steps like soaking, steaming and drying are involved in increasing the quality of the obtained rice. The parboiling aids in achieving higher head rice yield and it also enriches the nutritional properties of rice. Parboiling is generally done for these two important reasons and also to prevent spoilage due to molds and insects or pests (Siriamornpun, Sareepuang, Wiset, & Meeso, 2008) [16]. Parboiling of paddy is more common practice and is followed in different countries like Bangladesh, Myanmar, Sri Lanka, Malaysia, India, Spain, Italy etc and over nearly 50% of the paddy produced in the word is utilized after parboiling. In India, the consumption of parboiled paddy accounts nearly for 60% in the total paddy produced (Miah *et al*., 2002) [14].

Soaking of paddy is generally a slow process and it is greatly influenced by the diffusion of the water into the paddy (Bello, Tolaba, & Suarez, 2004) [3]. The desired moisture content of paddy before milling can be achieved by soaking of paddy as it enables quick and uniform water absorption of grains. Further, the moisture content can be increased by soaking the paddy at higher temperature or by increasing the soaking time (Miah *et al*., 2002) [14]. Soaking is an important step as low hydration may affect the gelatinization and parboiling of rice kernels (D'cruz, Chandran, Athmaselvi, Rawson, & Natarajan, 2023) [7]. Though soaking of paddy is an important process, improper soaking can result in colour change, off flavour development, leaching loss. So optimization of desired soaking temperature and time plays and major role in production of good quality rice kernels (Nkama *et al*., 2014) [15]. Thus, the current study focuses on optimizing the soaking and steaming time of black rice (Karuppu Kavuni) before milling.

2. Materials and Methods

2.1 Materials

Black rice (Karuppu Kavuni) used in the study was procured from the local market of Thanjavur, Tamil Nadu.

2.2 Soaking and Steaming Treatment

Black rice (Karuppu Kavuni) was subjected to soaking at room temperature for different time duration of for 10, 16, 24, 36 and 48 hours. After soaking the soaked samples were steamed at two different time periods of 15 and 20 minutes to determine the impact of steaming on milling and cooking of Karuppu Kavuni rice. The different treatment conditions used in the study were given in Table 1.

Table 1: Treatment Conditions

Treatments	Soaking Time (Hrs.)	Steaming Time (mins)
T 1	10	15
T 2	10	20
T 3	16	15
T 4	16	20
T 5	24	15
T 6	24	20
T 7	36	15
T 8	36	20
T 9	48	15
T 10	48	20

2.3 Milling of Black Rice

The black rice subjected to different treatment conditions was milled using a laboratory rubber roll paddy sheller (Satake, Japan) to remove the husk present in them. The moisture content of the samples was estimated and for milling approximately 250 – 300 g of sample was used. The quantity of brown rice and husk collected after the milling was determined. Further the shelling loss occurring during milling was also calculated. The standard milling procedures were adopted and the clearance between the two rubber rolls was predetermined based on the initial trials for optimum yield of rice kernels (Yadav & Jindal, 2008) [18]. The milled rice was then polished using an abrasive grain polisher (Satake, Japan), wherein an aspirator was provided to remove the bran present in the brown rice. 200 g of brown rice was used for polishing and the amount of the obtained polished rice, nooks and bran were determined. The following equations were used to determine the different milling parameters (D'cruz *et al*., 2023) [7]

$$\text{Milling Yield (\%)} = \left(\frac{\text{Weight of brown rice (kg)}}{\text{Actual weight of paddy (kg)}}\right) \times 100$$

$$\text{Head Rice Yield (\%)} = \left(\frac{\text{Weight of head rice(kg)}}{\text{Weight of milled rice (kg)}}\right) \times 100$$

$$\text{Brokens (\%)} = \left(\frac{\text{Weight of brokens (kg)}}{\text{Weight of milled rice (kg)}}\right) \times 100$$

2.4 Cooking characteristics

The milled rice was subjected to cooking to understand the characteristic changes occurring in Karuppu Kavuni rice during cooking and to evaluate its cooking characteristics. 5 g head rice obtained during milling was cooked using a beaker containing 50 ml of normal water and subjected to heat treatment using a water bath. The aroma, cooking time, volume, taste and the texture of the rice during cooking was determined. The rice was taken and placed in two microscopic glass slides and squeezed to determine the cooking stage (Billiris, Siebenmorgen, Meullenet, & Mauromoustakos, 2012) [4]. The disappearance of inner core indicates completely cooking and using this the cooking time was determined. The volume increase during cooking of rice was measured using a graduated measuring tube.

2.5 Textural Characteristics

2.5.1 Texture of milled rice kernels

The hardness of Karuppu kavuni rice kernel was determined using a hardness tester (Kiya Seisakusho, Japan) which is used to measure the hardness using a cylindrical probe of diameter 4.8 mm. The force needed for breakage of rice kernels were measured in kg (D'cruz *et al*., 2023) [7].

2.5.2 Texture of cooked rice

Texture Analyser – TA HD Plus (Stable micro system, UK) was used in the current study to evaluate the textural characteristics of the cooked Karuppu Kavuni rice. The samples were placed in the flat platform and the hardness, adhesiveness, chewiness, cohesiveness values were obtained by using a P/35 cylindrical probe. The compression force of 5 g was provided as an initial parameter to determine the essential textural parameters. The TA software was used for obtaining and interpretation of the data. Gumminess,

cohesiveness, springiness, hardness, chewiness and adhesiveness property of the cooked Karuppu kavuni rice were determined using the test curves obtained (Siriamornpun *et al*., 2008) [16].

3. Results and Discussion

3.1 Milling Characteristics

The milling characteristics of the black rice after different soaking and steaming conditions treatments 1 – 10 were provided below in the Table 2. The obtained results had low shelling loss which confirms that the different treatments had impact on the shelling loss of Karuppu Kavuni rice. The parboiling of the paddy has resulted in higher milling yield with minimal loss during the milling process (Guo, Chen, & Liu, 2014) [8]. The immature and broken grains which are collected with the presence of bran owing to their smaller size are termed as nooks. The quantity of nooks obtained due to the different treatments varied from 0.02 to 0.32 grams.

The milling of Karuppu Kavuni rice after 48 hours soaking and 20 min steaming (T 10) had very low shelling loss of 0.32 g which is the minimum loss values when compared with all other treatments. The polishing loss was minimal for the 16 hours soaking and 20 minutes steaming (T 4) samples; this indicates that this treatment combination can result in yield of high amount of good quality polished rice kernels. Furthermore the 48 hours soaking resulted in very low amount of broken grains after milling and polishing.

Table 2: Milling Characteristics of Black rice after different treatments

Treatments	T 1	T 2	T 3	T 4	T 5	T 6	T 7	T 8	T 9	T 10
Moisture Content (%)	10.2	10.3	11.7	10.8	11.0	11.0	11.0	10.7	11.1	10.8
Milling of treated black rice										
Paddy taken (g)	300	300	300	300	300	279.59	300	300	263.10	261.36
Brown Rice (g)	226.83	226.30	228.80	226.15	225.80	211.56	225.35	225.41	198.38	196.42
Husk (g)	72.41	72.74	72.65	72.82	73.27	67.45	73.81	73.81	63.94	64.62
Shelling Loss (g)	0.76	0.96	0.55	1.03	1.00	0.53	0.84	0.71	0.78	0.32
Polishing of milled black rice										
Brown Rice taken (g)	200	200	200	200	200	200	200	200	198.38	196.42
Polished Rice (g)	183.48	183.46	182.89	183.92	183.61	183.14	182.92	182.89	181.38	180.00
Bran (g)	15.90	16.16	16.44	15.84	15.52	16.09	16.00	16.51	16.15	15.70
Nooks (g)	0.09	0.07	0.02	0.05	0.08	0.05	0.32	0.15	0.16	0.24
Polishing Loss (g)	0.55	0.31	0.65	0.19	0.79	0.72	0.76	0.45	0.77	0.48
Brown Rice Broken (g)	1.12	1.26	1.06	0.76	0.93	0.42	0.18	0.25	0	0
Polished Rice Broken (g)	4.83	4.02	4.38	3.50	3.10	2.41	0.98	0.47	0.25	0.07

3.2 Cooking Characteristics

The increase in the soaking time of the samples, increased the cooking time of Karuppu Kavuni rice. Further, increasing the soaking time beyond 24 hours led to decrease in the volume of cooked rice. This indicates that the prolonging the soaking time beyond 24 hours had a negative impact on both cooking time and cooking volume of the rice obtained after cooking. The soaking treatments of 10, 16 and 24 hours had a higher cooking volume of 40. The aroma and taste of the cooked black rice was found to be good and normal (Sirisoontaralak, Keatikasemchai, Mancharoen, & Na Nakornpanom, 2020) [17] (Table 3). The results indicate that the different treatment conditions had no significant impact on the aroma and taste of the cooked Karuppu Kavuni rice. Though parboiling affects the whiteness, taste, aroma and texture of rice (Champathi Gunathilake, 2018) [5], in the current study the treated Karuppu Kavuni rice were found to possess good aroma and normal taste. The texture of the Karuppu Kavuni rice was lightly sticky after cooking.

Table 3: Cooking Characteristics of Black rice after different treatments

Treatment Conditions	T 1	T 2	T 3	T 4	T 5	T 6	T 7	T 8	T 9	T 10
Cooking Time (mins)	22	23	23	24	25	26	25	26	26	26
Volume (%)	38	40	40	40	40	40	37	38	36	37
Aroma	+	+	+	+	+	+	+	+	+	+
Taste	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal
Texture	Lightly Sticky	Lightly Sticky	Lightly Sticky	Lightly Sticky	Lightly Sticky	Lightly Sticky	Lightly Sticky	Lightly Sticky	Lightly Sticky	Lightly Sticky

3.3 Textural Characteristics

3.3.1 Texture of milled rice kernels

The increase in soaking duration increased the hardness values of the Karuppu Kavuni grains after milling. Both the treatments positively influenced the hardness of the rice kernels (Table 4). Parboiling of paddy results in reduction of porosity as the cracks and void spaces gets filled up; thus increasing the hardness of rice kernels. Similarly, the increase in soaking duration also affects the hardness of the rice (Ahmed, Forsido, Kuyu, & Keyata, 2023) [1]. The hardness of the Karuppu kavuni rice kernels after different treatment conditions varied from 4.2 – 6.8 kg.

Table 4: Hardness of milled rice kernels

Samples	Hardness (kg)
T 1	4.2
T 2	4.6
T 3	4.93
T 4	5.13
T 5	5.26
T 6	5.4
T 7	5.93
T 8	6.2
T 9	6.46
T 10	6.56

3.3.2 Texture of cooked rice

The soaking and steaming of black rice has greatly influenced the textural properties of cooked Karuppu Kavuni rice. Ahmed *et al*., 2023 [1] concluded that physico-chemical characteristics of paddy were greatly influenced by the soaking time. Similarly, Zhu *et al*., 2019 [20] reported that cooking and soaking process had impact on the mechanical changes in the paddy which in turn alters the final textural characteristics of the cooked Karuppu kavuni rice. The adhesiveness of the rice decreased (Figure 1) due to the different treatments this could be due to the leaching of starch during cooking (Lang *et al*., 2018) [13]. The rice kernels subjected to treatment conditions T 1 and T 6 had no adhesiveness and the value was found to be zero. The cooked rice kernels exhibit more elasticity as they tend to soften during cooking which can increase the other textural properties (Zhu *et al*., 2019) [20].

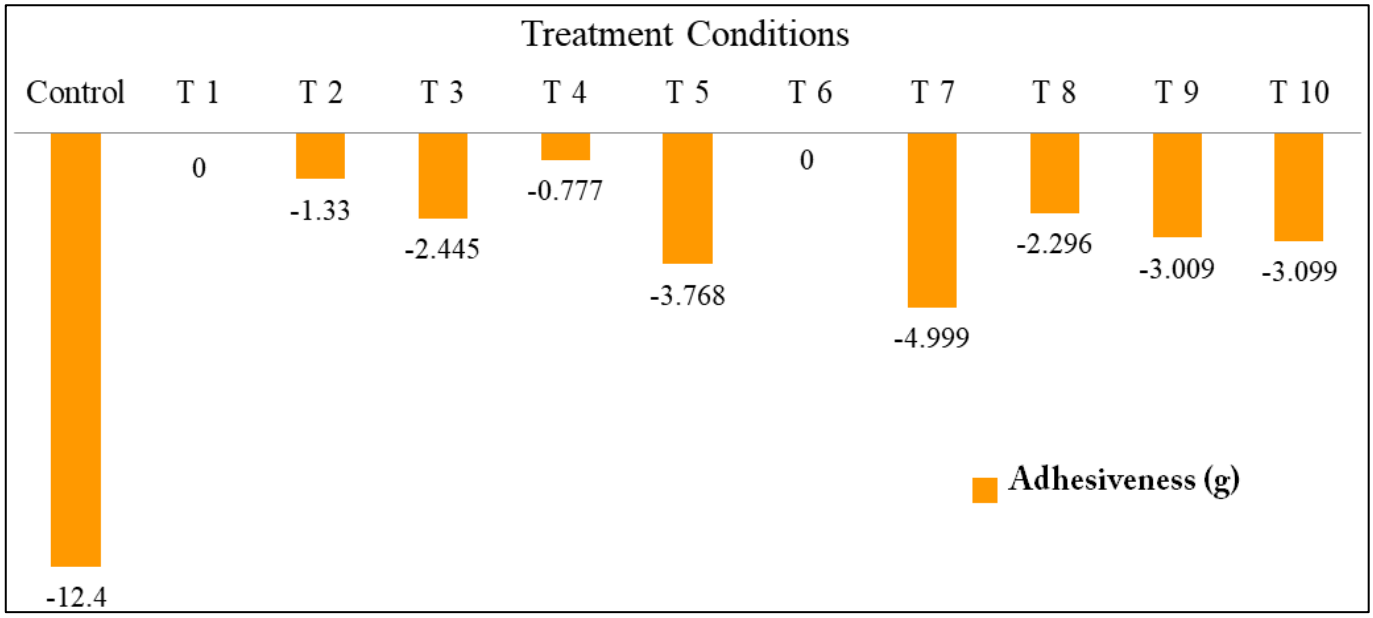

Fig 1: Adhesiveness of cooked Karuppu Kavuni rice subjected to different treatments

The different treatment conditions significantly influence on the hardness values of the cooked Karuppu Kavuni rice kernels (Figure 2). The hardness values increased and decreased based on the different treatments. The 24 hour soaking followed by 20 minutes steaming (T 6) resulted in higher hardness of the cooked Karuppu Kavuni rice kernels. The soaking of rice kernels for 10 hours decreased the hardness values, Where as the soaking for 48 hours increased the hardness values of cooked rice kernels compared to control sample. The increase in soaking and steaming time had a positive correlation with the cohesiveness, springiness, gumminess, resilience, and chewiness of the samples. On comparison with control sample, the different soaking and steaming conditions increased the gumminess, springiness, cohesiveness, chewiness and resilience of the cooked rice kernels (Figures 3 & 4).

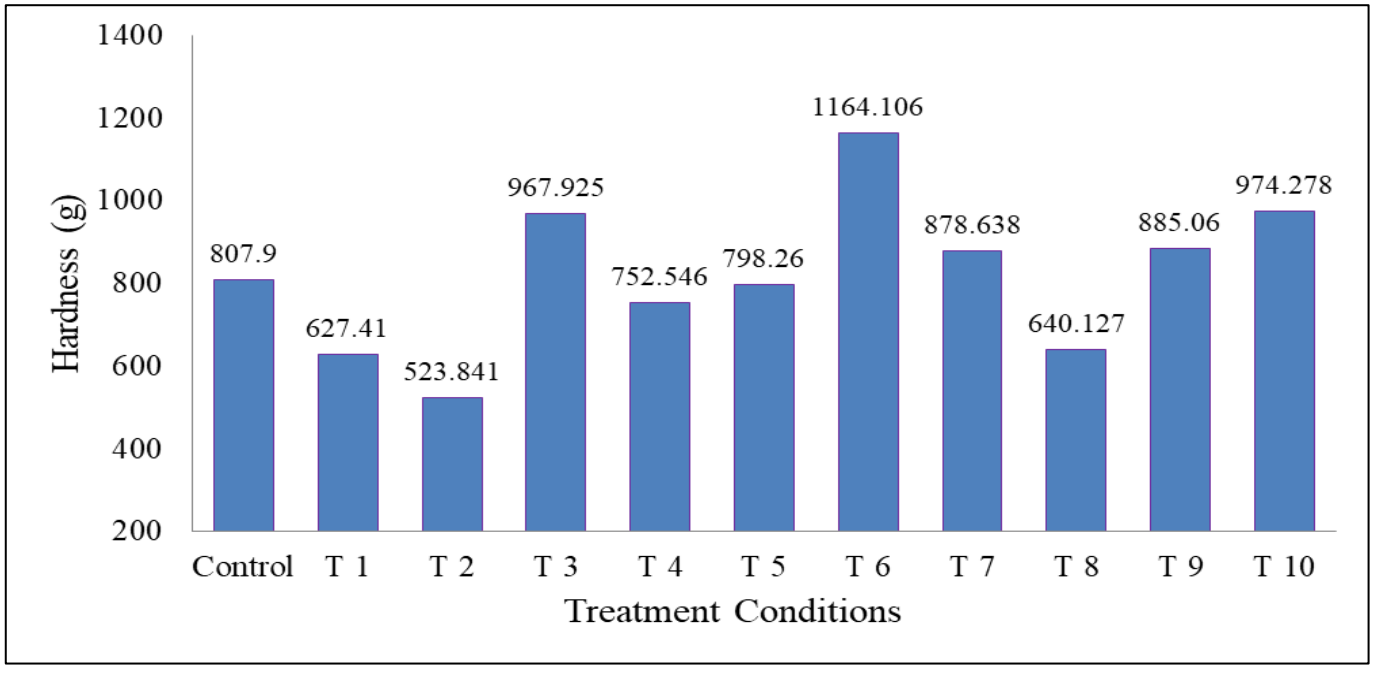

Fig 2: Hardness values of cooked Karuppu Kavuni rice subjected to different treatments

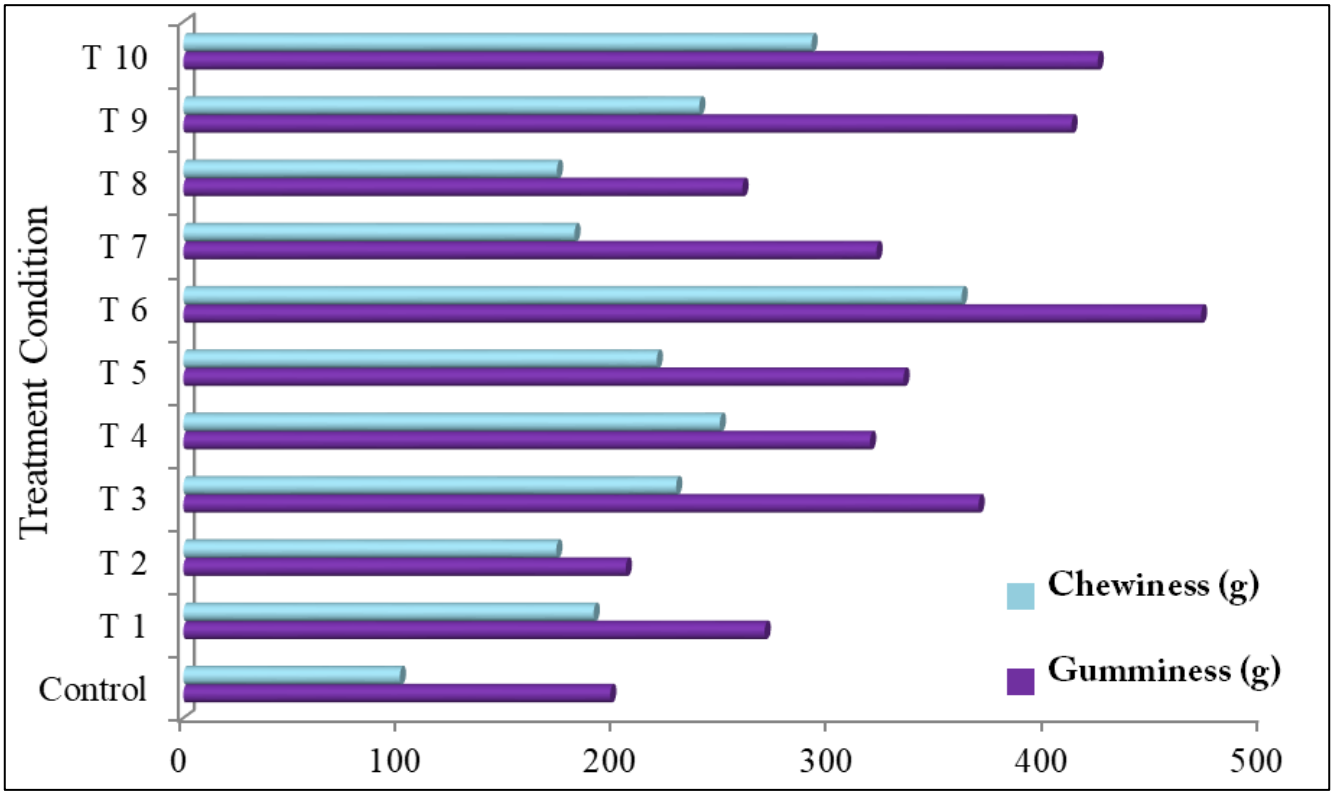

Fig 3: Gumminess and Chewiness values of cooked Karuppu Kavuni rice subjected to different treatments

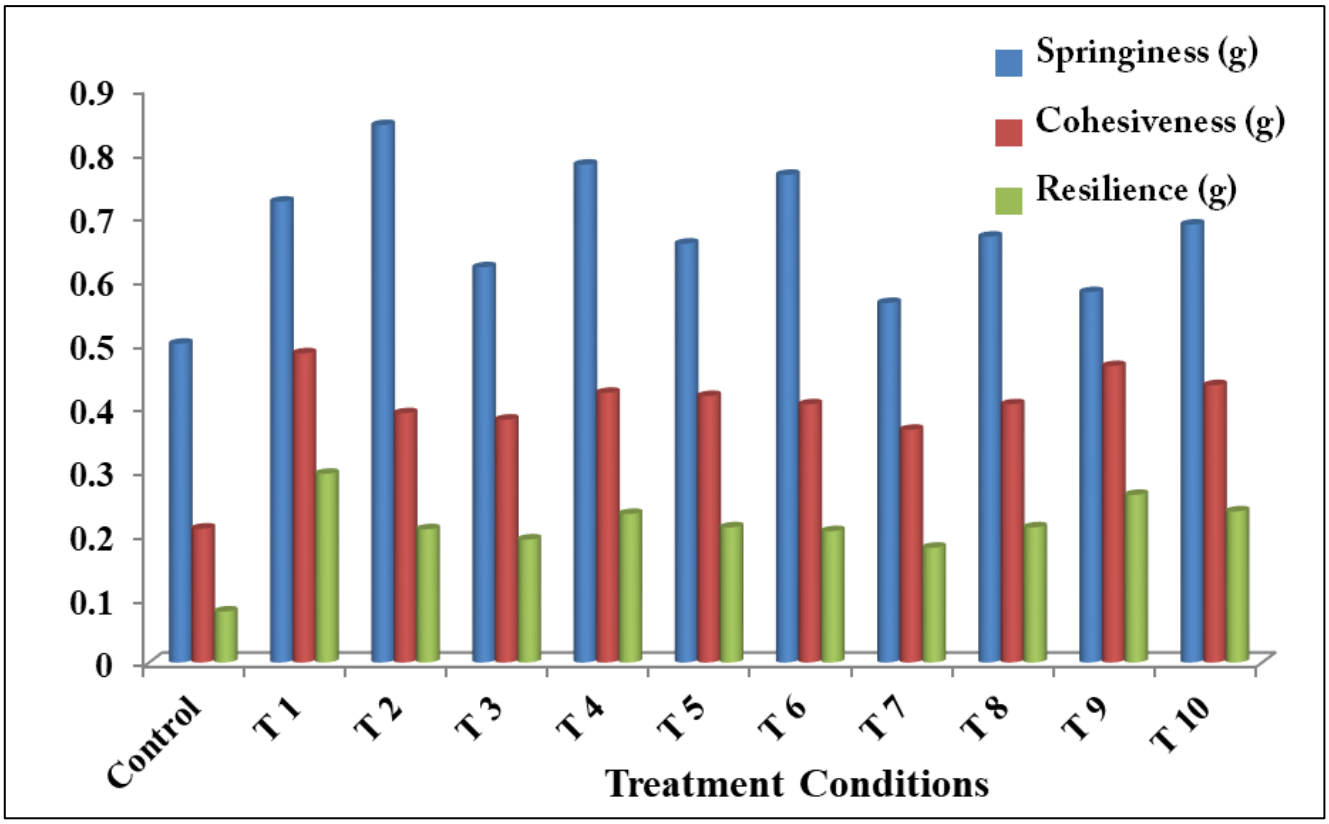

Fig 4: Cohesiveness, Springiness and Resilience values of cooked Karuppu Kavuni rice subjected to different treatments

4. Conclusion

The different soaking duration and steaming conditions had effect on the milling characteristics of the Karuppu kavuni rice. The parboiling treatment influences the cooking characteristics and results in good aroma and texture of the rice. The hardness values of the samples also had a significant increase after the treatments. The adhesiveness of the cooked rice samples decreased after the treatment as the gelatinization of the starch occurs during cooking. Thus the obtained results indicate that the different soaking and steaming conditions influence the milling, cooking and textural characteristics of Karuppu kavuni rice.

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