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Research Article

EFFECTS OF PARBOILING STEPS ON STARCH CHARACTERISTICS AND GLYCEMIC INDEX OF BASMATI (PB1121) RICE

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Abstract- Effects of soaking and steaming steps, individually on selected starch characteristics and GI of Pusa Basmati 1121 rice was evaluated. Rough rice was soaked at seven different temperatures (40-80°C) and soaking effect on starch content, A_m/A_p ratio, pasting properties, starch crystallinity, degree of gelatinization, grain transparency and GI of rice was determined. Similarly, rough rice was soaked at 65°C for 345 min and subsequently steamed at different steaming conditions to determine the steaming effect on these quality parameters. Starch content, A_m/A_p ratio, crystallinity, DG and GI of raw rice was determined as 73.24%, 0.59, 28.49%, 5.59% and 58.41, respectively. Soaking reduced the crystallinity up 14.08% whereas steaming reduced it up to 5.72%. Similar trend was observed for other parameters also. Both soaking and steaming decreased the pasting viscosities, converted crystalline form of starch into amorphous one, imparted translucency to the grains, and decreased the GI. However, soaking step achieved partial gelatinization whereas steaming step achieved complete gelatinization of starch. Soaking step absorbed the moisture to swallow the starch granules whereas steaming step ruptured the crystalline polyhedral structure to yield compact, amorphous and translucent rice.

Keywords- Crystallinity, Glycemic Index, Soaking, Starch, Steaming

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Introduction

Starch is the most important constituent of rice grain. Its share in milled raw rice grain at 14% moisture content (wb) is reported to be 71% [1]. Rice starch granule consists of two major components, amylose and amylopectin which are polymers of α-D-glucose units. Rice starch has a crystalline structure. Starch crystallinity decides the cooking qualities, pasting behavior and glycemic index (GI) of rice. Milling recovery is also influenced by the nature of rice starch. Rice with higher amount of crystalline starch fetches more breakage whereas rice having amorphous starch with lower crystallinity fetches smaller amount of milling breakage. Therefore, it is always economical to convert the crystalline starch into amorphous form prior to rice milling. This conversion is achieved through a gelatinization process called as 'parboiling'.

Parboiling brings either partial or complete gelatinization of starch depending on the severity of parboiling conditions. Parboiling induced gelatinization is generally accompanied by granule swelling, preferential amylose leaching and melting of crystallites [2]. Raw rice starch shows typical A-shaped pattern [3,4]. But after parboiling, such A-shaped crystallinity pattern is either reduced or completely destroyed depending on the severity of parboiling [5]. Presence of typical A-shaped crystals i.e. un-gelatinized starch granules causes the presence of white bellies/chalkiness in the endosperm that further contributes to higher amount of milling breakage [6]. Therefore, parboiling becomes indispensable to change the nature of rice starch and thereby reduction in milling breakage in the rice.

Conventional parboiling process involves three major steps namely soaking, steaming and drying. Among these steps, soaking and steaming are more critical steps as far as nutritional and structural changes inside rice grains are concerned. Both steps change the grain microstructure along with gross composition and distribution of nutrients within the grain [7-10]. Soaking is a hydration process during which water necessary for starch gelatinization diffuses into the rice kernel. Various studies demonstrated the effects of soaking step on rice quality characteristics [7-9]. Steaming step has also a great importance as complete starch gelatinization is achieved during it without removal of moisture from the soaked grains. During steaming, granular texture of starchy endosperm becomes pasty, compact and translucent, biological processes are inhibited and the enzymes are inactivated [10, 11].

As a result, it can be stated that starch is the most affected rice constituent during soaking and steaming steps of parboiling. The effects of parboiling steps on quality of rice starch can be assessed by evaluating different starch characteristics like amylose to amylopectin (A_m/A_p) ratio, pasting properties, percent crystallinity, degree of gelatinization (DG), grain microstructure, grain translucency etc. Previous studies reported that A_m/A_p ratio decides the cooking and eating qualities of rice [12, 13]. Pasting property of starch is a good indicator of the quality of rice starch. Rice with lower viscosity values, when cooked, gives non sticky, firmer grain with reduced gruel loss and improved texture [14]. After soaking and steaming, crystallinity is reduced whereas DG is increased, may be due to partial or complete gelatinization of starch [4, 13, 15]. Grain translucency is also the quality indicator of parboiled rice. Grain appearance is largely determined by the translucency of the grain and is inversely related to the amount of chalkiness [16]. Higher levels of chalkiness reduce the milling recovery [17].

Parboiling induced changes in the rice starch can also be evaluated by determining the GI of rice as GI value is mainly depend on starch characteristics of rice. In view of increased risk of lifestyle diseases, there is increased preference for foods 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 [18]. A report on thermal treatment of basmati varieties has shown reduction in GI below 55, making them low GI food [19]. Pathiraje *et al.* [20] investigated the effect of parboiling on in vivo glycemic response of different rice varieties and observed that parboiling caused significant reduction in glycemic response. Therefore, a systematic evaluation of the effect of parboiling steps on GI of rice may be helpful to the millers to produce rice with low GI.

Information on effects of parboiling steps i.e. soaking and steaming on starch characteristics and GI of any rice variety is useful to the millers and consumers in deciding the quality of parboiled rice. Consequently, an attempt was made in present study to parboil the PB1121 rice, the most popular basmati variety of India in present times, and to evaluate the effects of soaking and steaming steps on selected starch characteristics and GI of this variety.

Materials and Methods

Parboiling of rough rice

Rough rice (variety PB1121) was parboiled using conventional hydrothermal parboiling method. Rough rice of moisture content 13.77% (db) was obtained from the field of ICAR-Indian Agricultural Research Institute, New Delhi. Soaking was conducted in a distilled water using water bath (MAC, MSW-275, Micro Scientific Works (R), Delhi, India) at seven different temperatures 40, 50, 60, 65, 70, 75 and 80°C. 500 g of rough rice was soaked in 1.5 litres of water (1:3 ratio) till grains achieved critical moisture content (about 41%, db) of soaking [21]. Soaked grains were dried, de-husked and milled at 8% degree of milling. Milled grains were analysed for selected starch characteristics and GI. An optimum soaking temperature for PB1121 rice was considered as 65°C for 345 min, as optimized earlier [9, 21].

Another lot of rough rice was soaked in 500 ml of water at 65°C for 345 min and immediately steamed in horizontal autoclave (Tradevel Scientific Industries, New Delhi) at different steaming treatments. Steaming treatment involved 2 variables, steaming pressure (0.0, 0.5, 1 and 1.5 kg/cm^2) and steaming duration (5, 10, 15, 20 and 25 min). Coding of steaming treatments were done accordingly and presented in [Table-1]. Steamed grains were dried up to 14% (db) moisture content and milled at 8% degree of milling. Milled grains were used for further analysis.

Table-1 *Coding of steaming treatments (Kale et al., 2017)*

Steaming pressure (kg/cm^2)	Steaming time (min)	Code	Steaming pressure (kg/cm^2)	Steaming time (min)	Code
0.0	5	T_1	1.0	5	T_{11}
0.0	10	T_2	1.0	10	T_{12}
0.0	15	T_3	1.0	15	T_{13}
0.0	20	T_4	1.0	20	T_{14}
0.0	25	T_5	1.0	25	T_{15}
0.5	5	T_6	1.5	5	T_{16}
0.5	10	T_7	1.5	10	T_{17}
0.5	15	T_8	1.5	15	T_{18}
0.5	20	T_9	1.5	20	T_{19}
0.5	25	T_{10}	1.5	25	T_{20}

Starch and A_m/A_p ratio

Starch content of raw, soaked and steamed grains was determined by Anthrone reagent method [22]. Amylose content was determined using colorimetric method [22]. Amylopectin content was determined by subtracting the amylose content from starch content. A_m/A_p ratio was obtained using amylose and amylopectin contents of rice samples.

Pasting properties

A Rapid Visco Analyser (RVA Starchmaster 2, Newport Scientific Instruments, Australia) was used to determine the pasting properties of rice flours. Rice flour suspensions of 10% w/w (total weight: 28 g) were prepared and the Rice 1 profile of Newport Scientific instruments was used. The samples were held at 50°C for 1 min, heated from 50°C to 95°C, held at 95°C for 2.40 min and then cooled to 50°C and finally held at 50°C for 1 min. Peak viscosity, breakdown viscosity, final viscosity and setback viscosity were observed.

Starch crystallinity

X-ray diffractograms of flours of rice samples were determined using an Analytical Diffractometer (Pan Analytical, Phillips, Holland). The diffractograms were acquired over a 2θ (Bragg's angle) range of 4–30° with a step size of 0.02° [3]. Starch crystallinity (%) was evaluated by taking the ratio of peak area and total area obtained from the diffractograms as shown in [Eq-1] [4].

$$\text{Crystallinity (\%)} = \frac{\text{Area under peaks}}{\text{Total ppek area}} \times 100 \qquad ...[1]$$

Microstructure of rice grains

Microscopic images of rice grain samples were determined using Scanning Electron Microscope (Zeiss EVOMA10) at 20 kv and 10 Pa. Dried grains were cut using razor blade and specimens were mounted on aluminium studs [23]. Samples were coated with 24 nm thick coating of palladium and images were taken.

Degree of gelatinization (%)

DG of rice starch was determined using the method previously used by Dutta and Mahanta [4]. 200 mg rice sample was dispersed in 100 ml distilled water, stirred for 5 min and subsequently centrifuged at 1500 rpm for 25 min. 1 ml supernatant was then diluted to 10 ml with distilled water and 0.1 ml iodine solution was added. The method was repeated using 100 ml of 10 M KOH in place of distilled water and the absorbance of both solutions were recorded at 600 nm using UV-vis spectrophotometer (Specord, Analytik, Jena). DG was calculated using following equation [Eq-2].

$$\text{DG (\%)} = \frac{\text{Absorbance of fresh solution}}{\text{Absorbance of alkali solubilized solution}} \times 100 \qquad ...[2]$$

Grain transparency

Rice grains were kept on a glass platform and light was shined through them. Photographs of shined rice grains were taken to observe the rice grain transparency [24]. The arrangement made to determine the rice grain transparency is shown in [Fig-1].

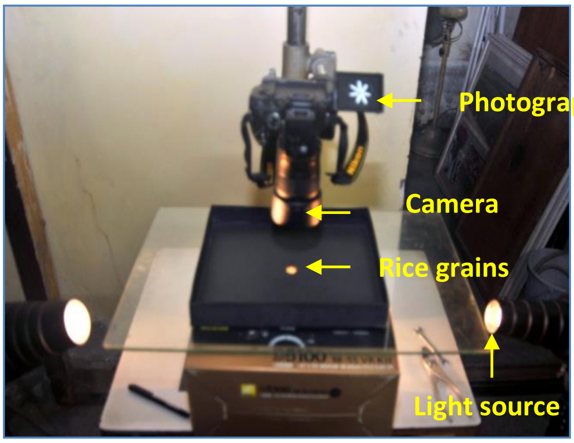


Fig-1 Arrangement for determination of rice grain transparency

Glycemic Index

GI of rice samples was determined using *In vitro* starch digestion method [12, 25]. Cooked rice samples were digested for 3 h at 40°C. Starch digestion was carried out using enzymes, pepsin from porcine gastrine mucosa (ref. 107195, Merck) and α-amylase from porcine pancreas (ref. A-3176, Sigma). During digestion, 1 ml aliquot was taken from each sample after every 30 min from 0 to 3 h. Subsequently, the total reducing sugar content of aliquots was determined by the 3,5-dinitrosalicylic acid (DNS) reagent method [26]. Maltose was used to prepare the standard curve. Starch digestion rate was conveyed as the percent starch hydrolysed at different five intervals (30 to 180 min). Areas under hydrolysis curve (AUC, 0-180 min) were obtained by equation given by Goni *et al.* [25]. Hydrolysis Index (HI) was calculated as the ratio of AUC for a rice sample and the AUC for a reference sample (white bread) and expressed as a percentage. Expected GI was then estimated using the following equation [Eq-3] [12].

$$GI = 39.71 + (0.549 \times HI) \quad \ldots [3]$$

Further, in order to make the GI values of PB1121 rice comparable with GI of different foods, it was converted in to the GI based on glucose by multiplying it with 0.7 [27].

Statistical analysis

Starch content, A_m/A_p ratio, pasting properties, crystallinity, DG and GI were measured in triplicate and the means were calculated. Duncan's multiple range test was performed to test the statistical differences in these properties as affected by parboiling steps. SPSS software (version 16.0) was used to conduct the tests. The significance was accepted at 5% levels of significance (α= 0.05).

In present study, results indicated that although statistical differences were observed in the selected starch characteristics and GI values due to variation in soaking and steaming treatments, from practical standpoint, these differences were very little to not significant. Hence, results of only relevant soaking and steaming treatments have been presented and discussed to draw appropriate conclusions.

Results And Discussion

Effect of soaking and steaming on starch content and A_m/A_p ratio

Starch content of raw PB1121 rice was found as 73.24%. However, this content decreased by 3.74 to 11.06% after soaking at all temperatures. Starch content varied from 65.14 - 70.50% in soaked rice. Decrease in starch content after soaking might be due to leaching of amylose during heating in water [28]. Starch content of rice was further decreased after steaming also. This content after soaking at 65°C for 345 min was 68.74%. But when rice soaked at 65°C for 345 min and further steamed under different steaming conditions, its starch content varied from 63.34 – 68.24%. Such steaming induced decrease in starch content might be due to formation of amylose-lipid complexes during hydrothermal process [7, 29]. Although, there was no leaching during steaming, starch gelatinization and formation of amylose-lipid complexes at these treatments might have made starch molecules less extractable. Decrease in starch content after parboiling has also been reported by Derycke *et al*. [29] and Sareepuang *et al*. [7]

A_m/A_p ratio is considered to be one of the most important factors affecting the rate of starch digestion [30]. Its value for raw PB1121 rice was found as 0.59 whereas this value varied from 0.52 - 0.59 after soaking at different temperatures. Decrease in A_m/A_p ratio after soaking might be due to decrease in amylose content during. At 65°C of soaking temperature (for 345 min), A_m/A_p ratio was found as 0.59. However, when rice soaked at 65°C for 345 min and subsequently steamed under varying steaming conditions, this ratio varied from 0.53 - 0.58. Higher reduction was observed at severe steaming treatments as compared to mild treatments. The reduction in A_m/A_p ratio after steaming was due to decrease in estimated amylose content. In present study, it was also noticed that at intermediate soaking temperatures (60-70°C), the change in A_m/A_p ratio was minimal. Even though this ratio decreased after soaking and steaming, its value was still higher than the normal value 0.25, reported for wheat, maize, potato and tapioca.

Effect of soaking and steaming on pasting properties

Pasting behavior is a key tool to determine the quality of rice starch. Pasting properties of rice starch can be related with cooking and textural properties of cooked rice. Present study noticed that both soaking and steaming changed the pasting properties of rice flours significantly (α=0.05) [Table-2]. Raw rice flour had the highest viscosity values whereas these values decreased gradually after soaking at 40 to 80°C [Table-2]. Soaking induced decrease in viscosity might be due to the decreased water binding ability, indicating the partial gelatinization of starch during soaking step at 60 and 80°C [31]. Negative values of breakdown viscosity showed that there was no distinct peak viscosity in case of all the flour slurries.

Although, viscosity values decreased after soaking, further decrease in viscosity was noticed due to steaming. The highest viscosity values, in case of raw rice were attributed to the crystalline nature of starch and its ability to bind more water. On the contrary, partially and completely gelatinized starch of soaked and steamed rice, respectively lost their water binding ability [31] and hence could not form pastes of high viscosities. Thus, from results, it can be understood that on cooking, raw rice will become sticky and softer whereas soaked and steamed rice become non-sticky and firmer. However, steamed rice would be non-stickier and firmer as compared to soaked rice. Dutta and Mahanta [4] reported that parboiling brings noticeable changes in the pasting properties of rice starch due to order–disorder transitions taking place at the molecular level.

Table-2 *Pasting properties of flours from raw, soaked and steamed rice*

Treatment	Peak viscosity (cP)	Final viscosity (cP)	Breakdown (cP)	Setback (cP)
Raw	1302i	3995i	-4d	2693j
Soaked rice				
40°C	1075h	3577h	-7bc	2502i
60°C	677g	2309g	-14a	1632h
80°C	526e	1505e	-6c	979g
Soaked-steamed				
T_5	634f	1576f	-8b	941f
T_{10}	674g	1596f	-4d	922e
T_{15}	251c	512c	-7b	261c
T_{16}	343d	633d	-4d	290d
T_{18}	183b	391b	-4d	208b
T_{20}	114a	216a	-1e	102a

Values followed by same alphabet in a column do not differ significantly (α=0.05).

Effect of soaking and steaming on starch crystallinity

Amylose is the major crystalline constituent in the rice starch. Crystallinity (%) measures the levels of crystalline amylose in rice [32]. It was observed that raw rice starch had 28.49% crystallinity whereas the rice samples soaked at 40, 60 and 80°C had 20.77, 19.02 and 14.08% crystallinity, respectively [Fig-2]. Manful *et al.* [32] also reported the crystallinity of raw rice (var. TOX 3108) as 24.6%. Like soaking, steaming also decreased the starch crystallinity. However, the extent of reduction in crystallinity in steamed rice was significantly (α=0.05) higher than the soaked rice samples. Rice when soaked at 65°C for 345 min followed by steaming at 1.5 kg/cm^2 pressure for 25 min showed 5.72% crystallinity. Decrease in crystallinity of rice (var. TOX 3108) from 24.6% to 19.7% after steaming (soaking at 90°C followed by open steaming for 8 min) has also been reported by Manful *et al.* [32]. Report also indicates that commercially parboiled rice showed crystallinity of 5.5% [32]. The decrease in crystallinity after soaking indicated the partial gelatinization of soaked rice. This partial gelatinization was accompanied by granule swelling, preferential amylose leaching and the melting of crystallites i.e. loss of X-ray diffraction pattern [2]. The loss in crystallinity was relatively lesser in soaked samples as compared to steamed samples, because steamed rice was completely gelatinized whereas soaked rice was only partially gelatinized.

Effect of soaking and steaming on rice grain microstructure

Microscopic images of raw, soaked and steamed rice grains were obtained using scanning electronic microscope (SEM) and relatively relevant images are presented in [Fig-3]. Results indicated that raw grain and grain soaked at 40°C had distinct polyhedral starch granules with air gaps and cracks in-between them. However, grains soaked at 60 and 80°C showed swelling of starch granules. Moreover, this swelling was more noticeable in the grain soaked at 80°C. Similarly, steamed rice samples did not show distinct starch granules and air gaps or any crack. Rice sample steamed for 5 min at 1.5 kg/cm^2 pressure (T_{16}) showed partial gelatinization of starch as only the swallowing of starch granules was observed whereas rice steamed for ≥10 min (T_{17}) showed complete gelatinization as starch granules formed a compact, hard mass with amorphous like structure.

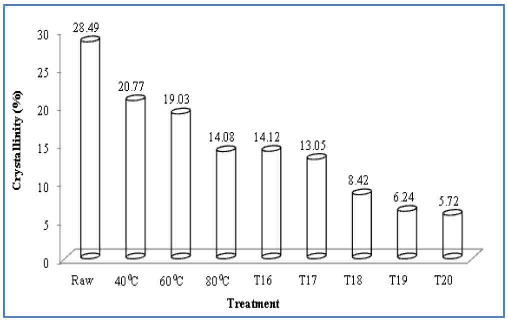
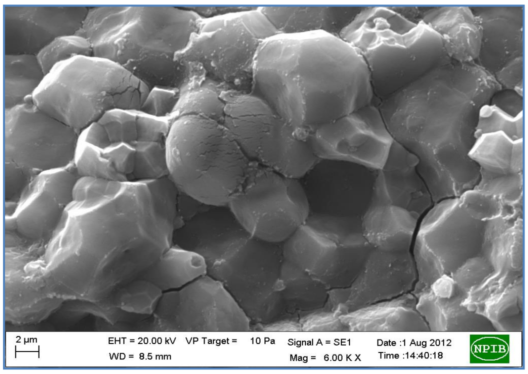
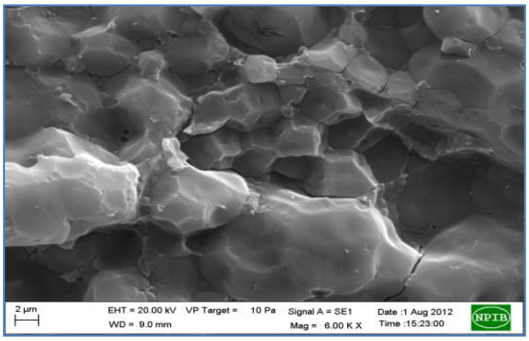


Fig-2 Crystallinity of raw, soaked and steamed rice starch

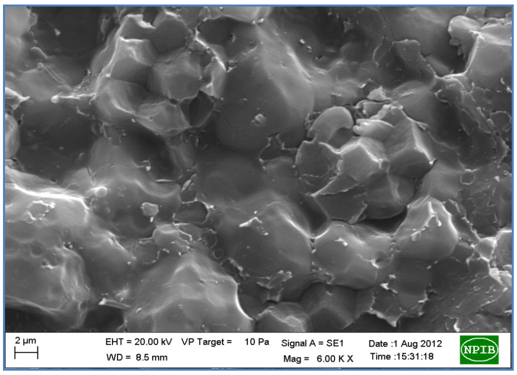
From results, it can be understood that water absorption during soaking step could swallow the starch granules and brought partial gelatinization of starch, whereas steaming step brought the complete gelatinization of starch and converted crystalline form of starch in to amorphous one. Thus, both the parboiling steps have inevitable roles in conventional parboiling process and hence cannot be avoided.



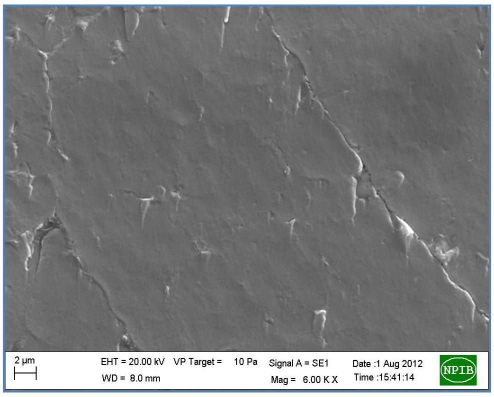
Raw rice



80°C



(T_{16})



(T_{17})

Fig-3 SEM images of raw, soaked and steamed rice

Effect of soaking and steaming on degree of gelatinization

DG value (%) indicates the amount of gelatinized starch present in the rice. Variation in DG (%) with severity of soaking and steaming steps is presented in [Table-3]. Both soaking and steaming showed significant effect on DG values (α=0.05). Results indicated that gelatinized starch content increased with severity of soaking. Its value was 5.59% for raw rice whereas it increased from 21.91 to 31.94% when soaked at 40-80°C. The highest degree of gelatinization was observed at 80°C, might be due to higher thermal exposure at this temperature [33]. Results also indicated that gelatinized starch content increased with severity of steaming. It varied from 38.00 - 61.84% when steamed at T_5 - T_{20}. Similar to the pasting properties, crystallinity and microscopic images as presented above, DG (%) values also indicated that soaking could achieve partial gelatinization only (DG value ≤31.92) whereas steaming achieved maximum possible gelatinization of starch (DG value up to 61.84) in PB1121 rice, thus indicating the specific roles and importance of both the steps.

Table-3 *Effect of soaking and steaming on DG (%) of rice starch*

Sample	Treatment	DG (%)
Raw	Untreated	5.59a
Soaked	40°C	20.91b
	60°C	24.22c
	80°C	31.92d
Soaked - steamed	T_5	38.00e
	T_{10}	41.18ef
	T_{15}	47.17f
	T_{16}	47.93f
	T_{17}	50.41g
	T_{18}	58.54h
	T_{19}	60.47i
	T_{20}	61.84i

Values followed by same alphabet in a column do not differ significantly (α=0.05).

Effect of soaking and steaming on rice grain transparency

Rice grain transparency provides the subjective measurement of grain translucency and chalkiness. It indicates the presence/ absence of chalkiness in the grains. In present study, it was determined by shining light through the rice grains. [Fig-4] represents the effect of soaking and steaming steps on rice grain transparency. It is evident from [Fig-4] that raw rice and rice soaked at 40°C was appeared to be rough, crystalline, polygonal cylinder with pointed ends whereas rice soaked at 60 and 80°C was appeared to be smooth, amorphous cylinder with rounded ends. The aforesaid changes in rice soaked at ≥60°C might be due to partial gelatinization of the starch during soaking [1, 6, 11].

It was also noted that the surface of steamed rice was appeared to be smooth, compact, translucent, amorphous cylinder with rounded ends, depending upon the severity of steaming. Steaming pressure affected the rice grain transparency. Increase in steaming pressure (at fixed steaming time of 25 min i.e. treatments T_5 to T_{20}) made grain more translucent and smoother. Similarly, increase in steaming time (keeping a constant steaming pressure of 1.5 kg/cm^2 i.e. treatments T_{16} to T_{20}) produced the rice with more compact, smoother and translucent grain [Fig-4]. Rice grain steamed at 1.5 kg/cm^2 pressure for 25 min (T_{20}) was appeared to be the most transparent grain. The change in grain transparency after steaming was due to the complete gelatinization of starch and thereby irreversible changes occurred in starch during steaming.

From results it can be observed that, soaking (at ≥60°C) alone could remove some amount of chalkiness in the grains but grains were still not completely translucent. However, steaming (≥T_{17}) produced completely translucent rice grains.

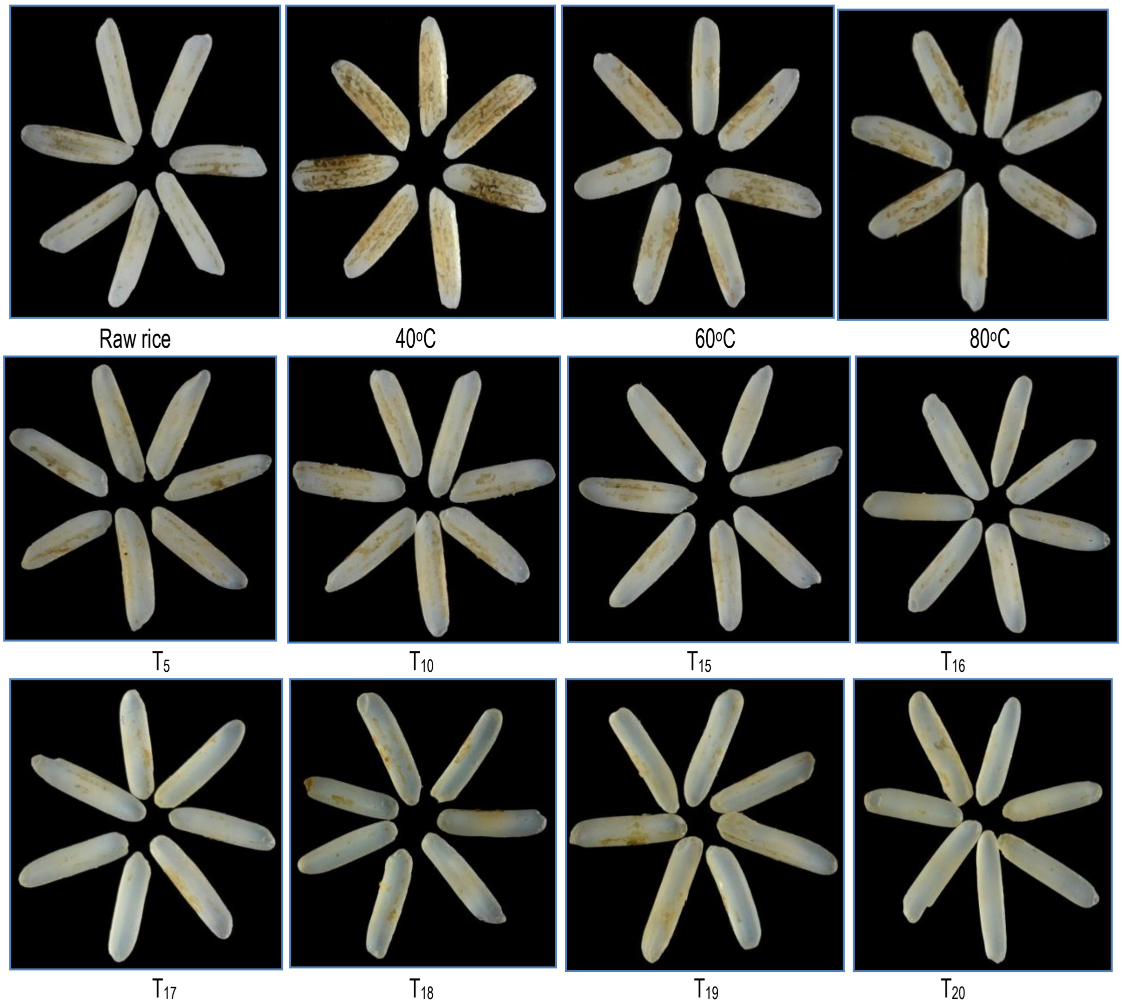


Fig-4 Effect of soaking and steaming steps on rice grain transparency

Effect of soaking and steaming on GI of PB1121 rice

Low GI foods are preferred more over medium and high GI foods. Therefore, determination of GI value of food materials is very important. In present study, results revealed that raw PB1121 rice is a medium GI (56-69) food, may be due to high amylose content (27.26%) and presence of stable amylose-lipid complex as observed from the X-ray diffractograms [9]. GI values of raw and soaked rice samples were found to be 58.41 and 54.31 - 57.96, respectively when glucose was the reference sample [Table-4]. GI of basmati rice was also reported to be 83 and 58 when reference samples were white bread and glucose, respectively [27]. Soaking at 40°C did not reduce the GI notably, but soaking at ≥60°C decreased the GI of PB1121 rice significantly (α=0.05) making it low GI (≤55) food [Table-4]. Such decrease in GI with increase in soaking temperature might be attributed to the formation of additional amylose-lipid complexes and partial gelatinization of starch at ≥60°C.

Like soaking step, steaming step also reduced the GI of PB1121 rice significantly (α=0.05). Results indicated that almost all the steaming treatments produced rice having GI<55 when glucose was the reference sample. In other words, these treatments produced rice having low GI and made it suitable for diabetics. Soaking step alone could reduce the GI of PB1121 rice up to 53.99, whereas steaming further reduced the GI of rice up to 47.04. Thus, parboiling found to be advantageous, in terms of GI value, as it could produce the PB1121 rice with low GI.

Table-4 *GI of raw, soaked and steamed rice samples*

Sample	Treatment	GI (bread=100)	GI (glucose=100)
Raw	Untreated	83.44i	58.41i
Soaked	40°C	82.80h	57.96h
	60°C	78.11g	54.67g
	80°C	77.59f	54.31f
Soaked - steamed	T_5	77.14f	53.99f
	T_{10}	75.01e	52.50e
	$T1_5$	73.06d	51.14d
	T_{16}	75.94e	53.16f
	T_{17}	72.24c	50.57c
	T_{18}	70.28b	49.20b
	T_{19}	67.20a	47.04a
	T_{20}	67.43a	47.20a

Values followed by same alphabet in a column do not differ significantly (α=0.05).

Conclusions

Soaking and steaming are the most important steps of rice parboiling due to their severe effects on starch characteristics, nutritional composition and distribution in the grains. Hence, an attempt was made in present study to evaluate the effect of soaking and steaming steps, individually on selected starch characteristics and GI of PB1121 rice. Results indicated that both soaking and steaming steps decreased the starch content, decreased the pasting viscosities, converted the crystalline form of starch in to amorphous one, imparted translucency to the grains, and decreased the GI value through the process of gelatinization. However, soaking step achieved partial gelatinization only, whereas steaming step achieved the complete gelatinization of rice starch. The main purpose of soaking step was found to increase the moisture content, and thereby swallowing of the starch granules. In contrast, the main purpose of steaming step was found to achieve the complete gelatinization of rice starch, and thereby making the grain compact, amorphous and translucent.

Application of research:
The study has systematically determined the effects of soaking and steaming steps of parboiling process on starch characteristics and Glycemic Index (GI) of Pusa Basmati 1121 rice. Literature reveals that no reported information is available on the individual effects of soaking and steaming on starch and GI of rice. Literature also reveals that no such study has been conducted on basmati varieties of rice. Therefore, results of this study would be useful to the rice millers, especially for basmati rice millers, to produce parboiled PB1121 rice with lower GI and better quality.

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Author Contributions:
All authors equally contributed

Abbreviations:

wb	wet basis
db	dry basis
GI	glycemic index
A_m/A_p	amylose to amylopectin ratio
DG	degree of gelatinization
PB	pusa basmati
Min	minutes
%	percent
HI	hydrolysis index
cP	centipoise

Conflict of Interest
It is stated that there is no conflict of interest for publication of this article. All the contributors have been duly acknowledged.

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