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Post-Harvest Loss Minimization of Rice Bran for Quality Bran Oil Production in Bangladesh

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Abstract

The effect of physical and chemical treatments on the yields of rice bran oil, free fatty acid (FFA), peroxide value (PV), acid value (AV), iodine value (IV), saponification value (SV), refractive index, relative density and fatty acid profiling in rice bran stabilization was examined. We hypothesized that rice bran oil percentage might be varied over varietal difference and mode of rice processing such as unparboiling and parboiling milling. In our experiment, we have used two popular high yielding variety (HYVs) such as BR16 and BRRI dhan28 and found BRRI dhan28 HYV had produce significantly higher oil content % than BR16 at parboiled condition. It is also noticeable that oil extraction showed better performance at parboiled milling than unparboiled condition in term of lower FFA% also. We further treated our experimental rice bran (RB) by three treatments such as untreated (control), heat treated (incubate at 130 - 135°C for 2 hours) and chemically treated at the rate of 30 ml HCl Kg^{-1}. In case of heat treated RB, the yields of RBO oil content % had retained a significant level (25.38%) and FFA% remain lowest (3.3%) among all treatments at 28 days. In addition, the heat-treated RB had produced almost similar oil quality as freshly available RB in respect to fatty acid profiling and other oil chemistry parameters. Our data reveals that physical treatment such as heat treatment found significantly efficient over chemically treated and untreated RB in lowering FFA% for a period of 28 days storage.

Keywords: *Rice Bran; Bran Oil Production; Bangladesh*

Introduction

In Bangladesh, consumption of edible oil is 26.57g$Capita^{-1}day^{-1}$ or 9.70 $KgCapita^{-1}annum^{-1}$ which is lower than per capita consumption of Pakistan and India as 14 kg and 13.92 $KgCapita^{-1}annum^{-1}$ respectively. Therefore, the total requirement of edible oil becomes approximately 15.09 Lakh million tons (MT) for the population of 160 million. Since oil seeds such as mustard seed, sesame seed and ground nut seed provide about 2.19 Lac MT of edible oil, the country still needs to import 13.44 Lac MT of crude edible oil for obtaining 12.90 MT of refined edible oil to meet the present local demand. The Perspective Plan of Bangladesh 2010-21 aimed at increasing the production of domestic oil seeds for providing the population with 40 g$Capita^{-1}day^{-1}$ or 14.6 $KgCapita^{-1}annum^{-1}$ of edible oil in 2021. RBO is considered to be good oil for health as it contains orzonal considered to be good for heart. Rice Bran is a light red covering upper part of the rice under the husk of paddy but it depends on the rice production and proper utilization of rice plant (Paddy) to bring about RB. Therefore, it is needed to turn all the manual rice mill to semi auto (introduce rubber roll huller mill in place of engleburg huller mill) and Auto Mill. Unless measures are taken to increase the domestic production of edible oil out of domestic seeds or Rice Bran, there will be more drainage of foreign currency to meet the increased demand in 2021 [1,2]. In 2017, Siddiquee., *et al*. [3]compared dietary intake of RBO with other edible oils such as soybean oil (SBO), mustard oil (MTO) and butter oil (BTO) to evaluate the health effects on *in-vivo* experimental long Evan rat model. He clearly showed that dietary intake of RBO of antioxidant enriched BR5, found potentially the best among other tested edible oils such as mustard oil, soybean oil and butter oil in term of least increment of blood cholesterol and triglyceride. So, good quality of edible RBO has an immense prospect in Bangladesh considering both health and economic benefits. In this regard, Rice bran oil industry is necessary to develop this potential edible oil sector and thereby reduce the dependence on imported crude oil in Bangladesh. Rice bran oil (RBO) has a commercial value in increasing RBO industries in Bangladesh. Since it is a fast-growing industry in our edible oil market, so robust steps of collection and storage facilities of Rice Bran (RB), which is the prime material for RBO extraction, are very necessary to nourish this prominent industry in Bangladesh. Postharvest losses (PHL) in quality rice bran collection occur from a number of causes, such as improper handling, lack of storage, mixture of husk with bran, increased free fatty acid (≥ 6% FFA) percentage due to bio deterioration by lipase enzyme etc. Rice bran oil helps in reducing serum cholesterol level and prevents risk of heart diseases. Rice bran contains lipase enzyme which is suitably active at 35 to 40°C [4]. Lipase and oil present in cells come in contact with each other due to rupturing of cells during rice milling. Due to hydrolysis of triacylglycerols into free fatty acids by lipase, FFAs decrease the shelf life of rice bran and makes it unsuitable for human consumption [5]. Generally, RBO industries in Bangladesh does not have a noticeable RB collection system rather it depends on broker (agent) based RB collection from different auto, semi auto rice mills along with rubber hollers. Transportation is also a challenge as no special RB collection vehicles are seen till today. We have gathered primary information that RBO industries usually receive RB containing 10 - 13% FFA at mill gates. This is a core point of investigation how to get good quality of RB from milling point to RBO processing unit keeping FFA% of RB in ranges (3 - 6%). During this project period, we have visited a total of 18 mills including 7 running rice bran oil (RBO) producing mills and 11 auto rice mills in Mymensingh, Jamalpur, Sherpur, Tangail, Bogra, and Rongpur districts. We have noticed that most of the RBO mills are facing constrains related to get fresh rice bran even during rice harvesting seasons and sometimes on the top, artificial bran crisis occurs due to inappropriate proportion of exporting rice bran for higher economic benefit to neighboring country. On the other hand, local RBO mills are facing difficulties in marketing DORB due to heavily imported DORB from neighboring country in lower price for feed industries. Through this project, we were aimed to brief up the current status of RBO industries and possible way of making advancement regarding this industry in Bangladesh. Coordinated approaches of RB collection is essential and scientific interventions are required in this regard. On the other hand, DORB also has a huge market in cattle, fish and poultry feed, silica gel and insulation bricks industries in our country. DORB is produced as by product during the production of rice bran oil. In this project, we would like to investigate all previously mentioned challenges into account and we will evaluate chemical as well as physical treatments of RB and DORB whether these can impact on increasing good quality RBO and associated feed quality respectively. We have objectives to assess suitable chemical or physical treatments for stabilization of RB and comparative study to determine the nutritional quality assessment of stabilized RB derived RBO and RBO byproducts.

Material and Methods

Free fatty acids (FFA), Peroxide value (PV), Iodine value (IV), Saponification value (SV), Refractive index (RI), specific gravity was determined by using standard methods [6]. Colors of the oil were measured by using Lovibond tintometer (Model F, Effem Technologies Pvt. Ltd., New Delhi, India). Fatty acids of triglycerides were analyzed by preparing methyl esters according to a conventional procedure consisting of saponification followed by acidification and finally methylation using diazomethane as per the reported method [7]. Gas chromatographic (GC) analysis of fatty acid methyl esters were carried out using a NUCON SERIES 5700 of data station 0 - 2.5 mV range and < 1.5s response rate. A 2m x 2 mm stainless steel 10% Silar 7C column packed with 60 - 120 mesh Gas Chrom Q will be used. The injector and detector temperatures have to be maintained at 240°C. The column temperature is set at 160°C for 5 minutes and then ramped at a rate of 5°C per min to a final temperature of 220°C and kept there for 20 minutes. Fatty acids were tentatively identified by comparison with retention times of authentic reference samples. The data were tabulated and subjected to two ways ANOVA, test of significance, means and standard deviation using SPSS version 20. Moisture Content, (%w/w), Ash Content, (%w/w), Volatile Matter, (%w/w), Fixed Carbon, (%w/w), Higher Calorific Value, kcal/kg were analyzed by standard analytical procedures such as IP 2016-65, IP 4/58, Muffle Furnace, Physical and Bomb Calorimeter respectively. All test parameters were analyzed in triplicate and the whole research was conducted under Grain Quality and Nutrition (GQN) laboratory of Bangladesh Rice Research Institute (BRRI), Gazipur, Bangladesh. The SPSS, version 20 was applied in the statistical analysis of the experimental data. Analysis of variance (ANOVA) followed by DMRT was applied for mean separation. The level of significance was set at $p < 0.05$. Triplicate samples were analyzed all for parameters.

Results

Rice bran oil percentage varied over varietal difference and mode of rice processing such as unparboiling and parboiling milling. In our experiment, we have used two HYV such as BR16 and BRRI dhan28 and found BRRI dhan28 HYV produce higher oil content % and lesser FFA% at parboiled condition than unparboiled (Figure 1, Table 1 and Table 2). Since lipase activity of bran increase the FFA% and decrease the oil % of rice bran, so we had treated our experimental rice bran by three (3) treatments such as untreated (control), heat treated (incubate at 130 - 135°C for 2 hours and chemically treated at the rate of $30 mLKg^{-1}$ HCl at parboiled milling condition (Figure 2-4). Referring to figure 2, our data clearly demonstrated that untreated rice bran at the 28 day of harvesting bran had grained the highest FFA% and lowest oil % compare to freshly harvested rice bran. On the other hand, heat treated rice bran at the 28 day of harvesting bran had retained similar FFA% and oil % compare to freshly harvested rice bran (Figure 3). But the chemically treated rice bran did not perform satisfactory in this regard (Figure 4). Oil% and FFA% of parboiling milling processed rice bran showed higher value than unparboiled milling processed rice bran at three treatments such as untreated, heat treated and chemically treated (Figure 5-7). Acid Value (as

KOH), mg/g, Free Fatty Acid as oleic (FFA) %, Peroxide Value (PV) meq O_2/kg, and Iodine Value (IV) (Hanus method) and oil content % had significant variation among untreated, heat treated and chemically treated treatments at parboiled milling condition but Saponification Value (SV) (as KOH) mg/g, Refractive Index at 40ºC and Relative Density at 300C did not shown any difference (Table 3). Fatty acid profiling (FAP) of selected treated samples were found mostly similar quality of saturated and unsaturated fatty acids composition between fresh and heat-treated oils (Table 3). It is further noticeable that heat treated rice bran could produced quality bran oil in respect to FAP and other tested oil chemistry parameters compare to freshly isolated rice bran even after 28 days (Table 4). RBO byproducts such as rice wax and bleaching earth compositions are demonstrated as tabular form in table 5 and table 6.

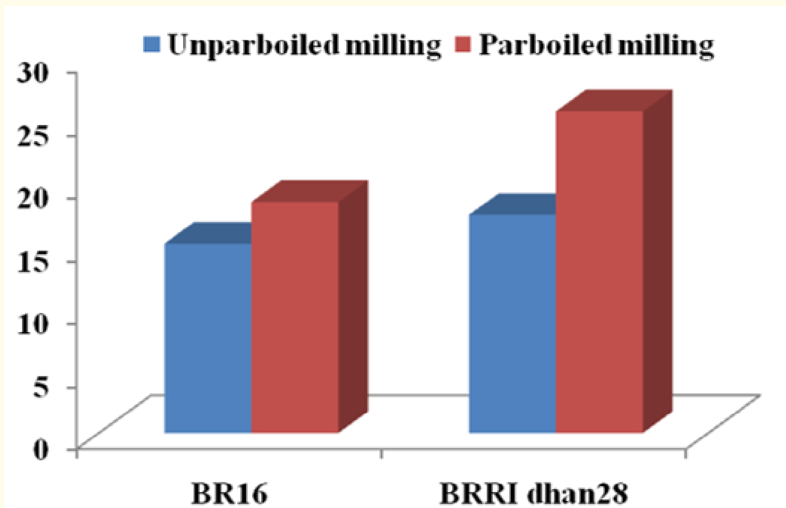

Figure 1: *RBO oil content % varied over HYV varietal difference and different milling processes.*

Milling Process	RBO content (%) of BR16	RBO content (%) of BRRI dhan28
Unparboiled milling	15.08 ± 0.52[a]	17.38 ± 1.01[b]
Parboiled milling	18.41 ± 0.91[c]	25.63 ± 0.75[d]
Any two means having common letter (s) in both row and column are not statistically different at a P < 0.05, as measured by the Duncan Multiple Range Test (DMRT).		

Table 1: *RBO content (%) of different HYVs at different rice milling processes.*

Milling Process	FFA (%) of BR16	FFA (%) of BRRI dhan28
Unparboiled milling	8.75[a]	4.15[b]
Parboiled milling	6.90[c]	2.00[d]
Any two means having common letter (s) in both row and column are not statistically different at a P< 0.05, as measured by the Duncan Multiple Range Test (DMRT).		

Table 2: *FFA (%) of different HYVs at different rice milling processes.*

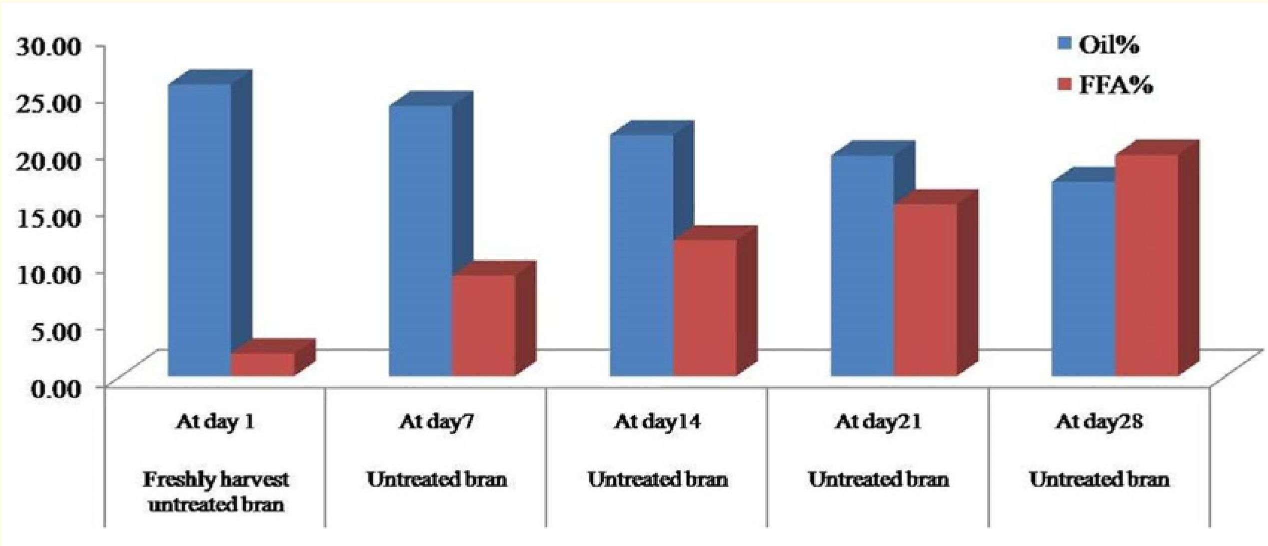

Figure 2: *Untreated BRRI dhan28 bran were used for extracting Oil content% and measuring FFA% from freshly harvest to 28 days of storage at room temperature and parboiled milling condition.*

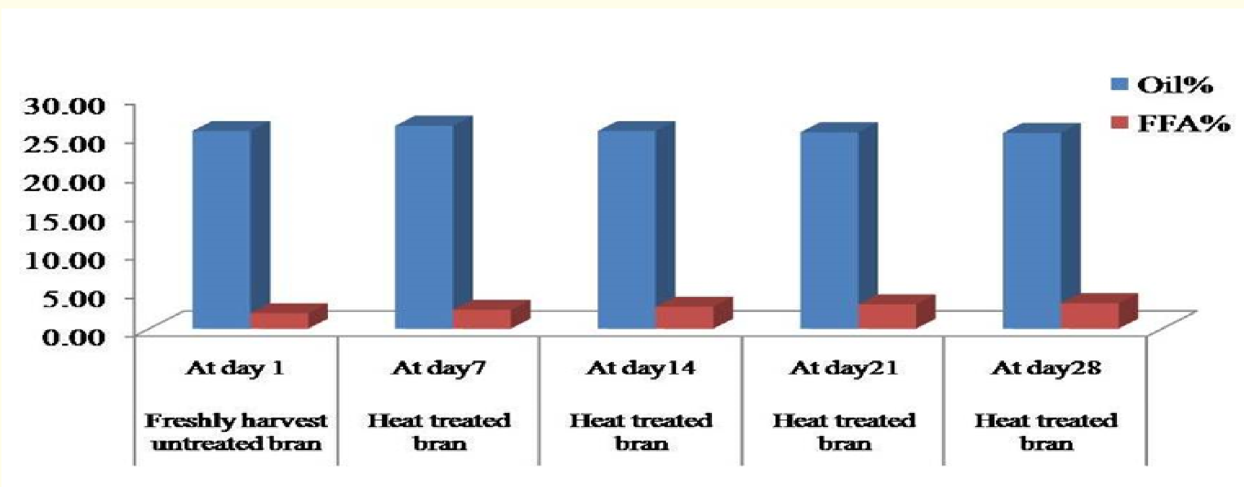

Figure 3: *Heat-treated BRRI dhan28 bran were used for extracting Oil content% and measuring FFA% from freshly harvest to 28 days of storage at room temperature and parboiled milling condition.*

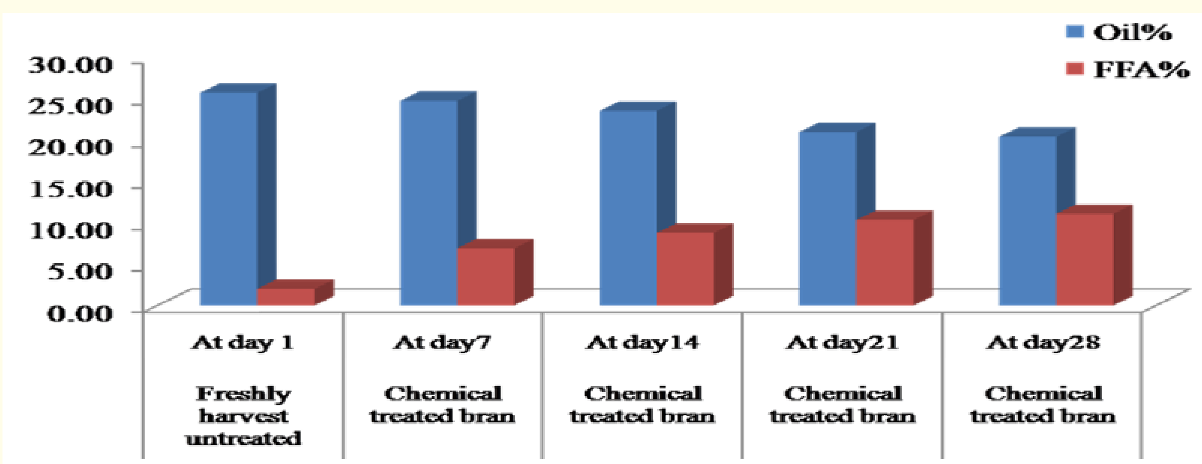

Figure 4: *Chemically treated BRRI dhan28 bran were used for extracting Oil content% and measuring FFA% from freshly harvest to 28 days of storage at room temperature and parboiled milling condition.*

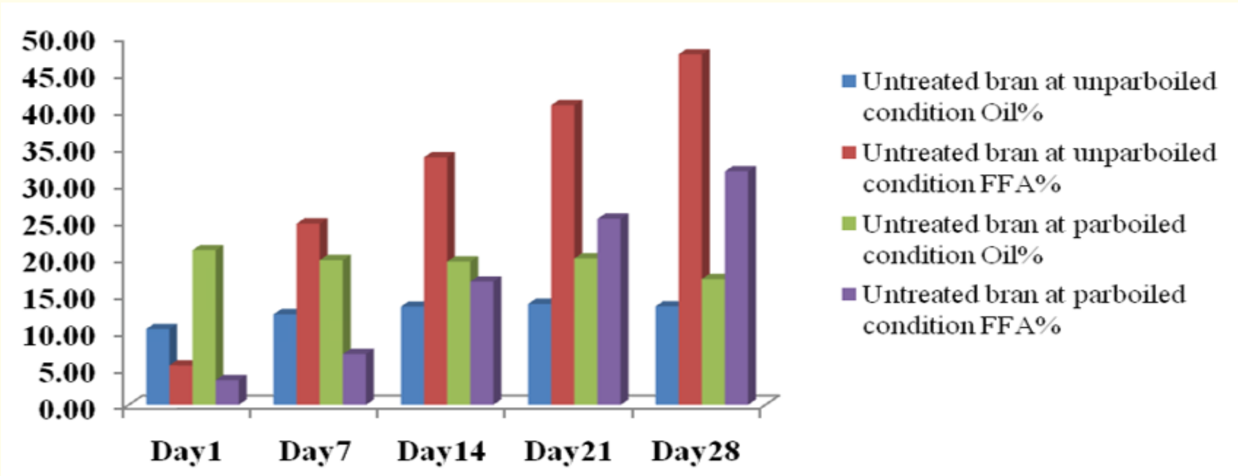

Figure 5: *Oil% and FFA% of untreated rice bran at both unparboiled and parboiled milling condition.*

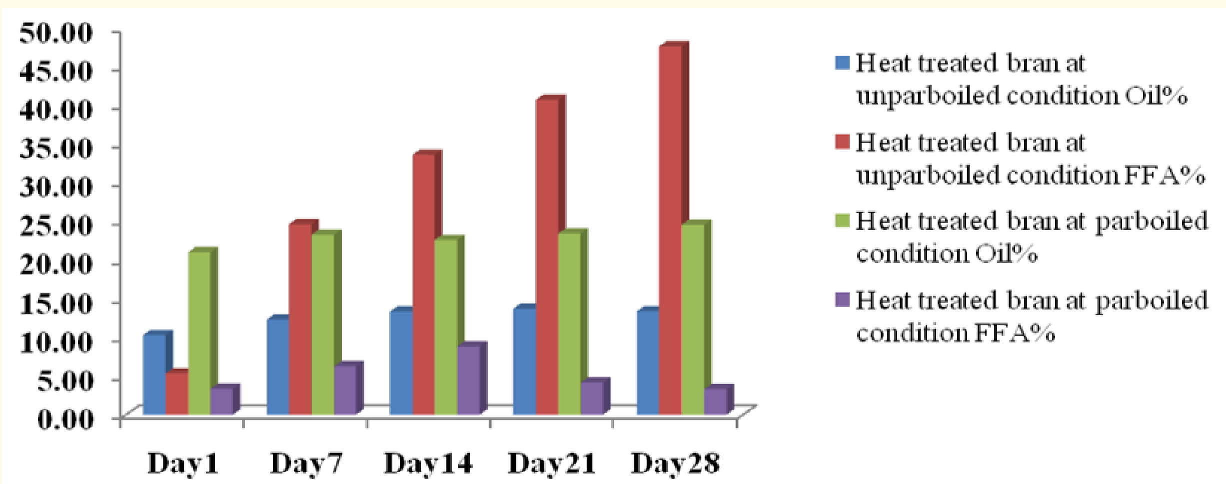

Figure 6: *Oil% and FFA% of heat treated rice bran at both unparboiled and parboiled milling condition.*

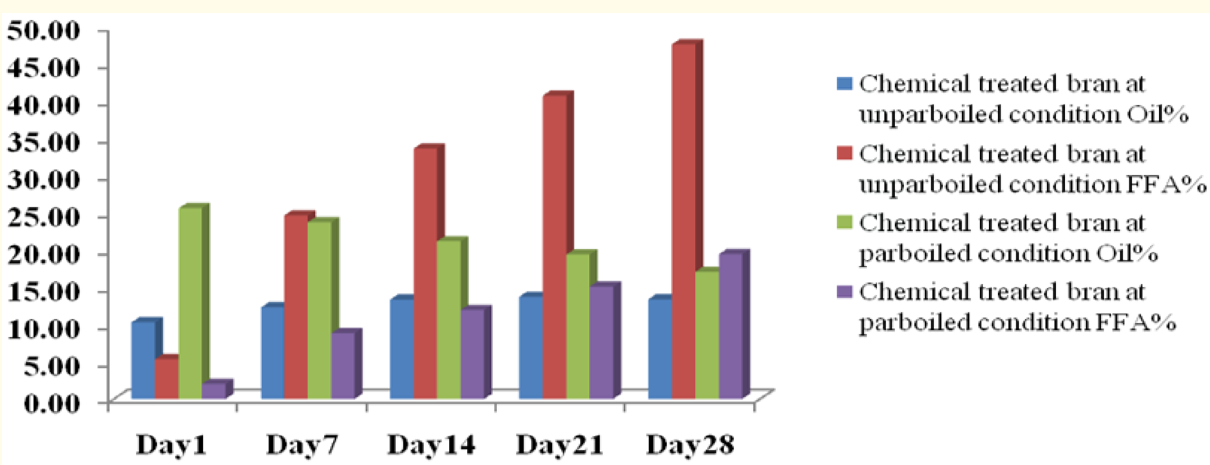

Figure 7: *Oil% and FFA% of chemically treated rice bran at both unparboiled and parboiled milling condition.*

Test Parameters	Crude oil extracted from three different rice bran (RB)		
	Untreated as Control (At day28)	Heat treated (At day28)	Chemical treated (At day28)
AV (as KOH), mg/g	38.90[a]	6.60[b]	22.08[c]
FFA as oleic (FFA), %	19.45[a]	3.30[b]	11.04[c]
PV, meq O_2/kg	3.68[a]	2.07[b]	4.03[c]
IV by Hanus method	97.00[a]	90.00[b]	105.00[c]
SV as KOH, mg/g	181.00[a]	182.00[b]	180.00[c]
Color by Lovibond	51.00[a]	54.00[b]	56.00[c]
Refractive Index at 40°C	1.46[a]	1.47[a]	1.46[a]
Relative Density at 30^{0}C	0.90[a]	0.91[a]	0.91[a]
Oil Content %	17.08[a]	25.38[b]	20.34[c]
Aflatoxins (B_1, B_2, G_1, G_2)	ND	ND	ND
Myristic Acid %	0.44[a]	0.41[b]	0.43[a]
Palmitic Acid %	23.90[a]	24.26[b]	23.07[c]
Stearic Acid %	1.32[a]	1.32[a]	1.23[b]
Oleic Acid %	42.29[a]	42.85[b]	42.52[c]
Linoleic Acid %	30.02[a]	29.18[b]	30.54[c]
Linolenic Acid %	1.20[a]	1.24[b]	1.17[c]
Arachidic Acid %	0.49[a]	0.49[a]	0.53[b]
Ecosadoic Acid %	0.30[a]	0.22[b]	0.26[c]
Any two means having common letter (s) in row are not statistically different at a P< 0.05, as measured by the Duncan Multiple Range Test (DMRT). ND: Not Detectable.			

***Table 3:** Quality parameters of Rice Bran Oil (RBO) extracted from different treated BRRI dhan28 rice bran (RB) at parboiled milling condition.*

Test Parameters	Crude oil (Parboiled condition) extracted from different rice bran (RB)	
	Untreated (Fresh)	Heat treated rice bran
AV, (as KOH), mg/g	4.00[a]	6.60[b]
FFA as oleic (FFA), %	2.00[a]	3.30[b]
PV, meq O_2/kg	0.53[a]	2.07[b]
IV by Hanus method	91.00[a]	90.00[b]
SV as KOH, mg/g	182.00[a]	182.00[b]
Color by Lovibond	47.00[a]	54.00[b]
Refractive Index at 40°C	1.46[a]	1.47[a]
Relative Density at 30^{0}C	0.90[a]	0.91[a]
Oil Content %	25.63[a]	25.38[a]
Aflatoxins (B_1, B_2, G_1, G_2)	ND	ND
Myristic Acid %	0.43[a]	0.41[a]
Palmitic Acid %	23.95[a]	24.26[b]
Stearic Acid %	1.36[a]	1.32[b]
Oleic Acid %	42.44[a]	42.85[a]
Linoleic Acid %	29.03[a]	29.18[a]
Linolenic Acid %	1.21[a]	1.24[a]
Arachidic Acid %	0.48[a]	0.49[a]
Eicosanoic Acid %	0.21[a]	0.22[a]
Any two means having common letter (s) are not statistically different at a P< 0.05, as measured by the Duncan Multiple Range Test (DMRT). ND; Not Detectable.		

***Table 4:** Quality parameters of Rice Bran Oil (RBO) extracted from BRRI dhan28 rice bran (RB) at parboiled milling condition.*

Parameters	Method/Instrument	Value
AV as KOH, mg/g	IS 548-1964	15.08 - 16.99
Carbon (%)	C H N S Analyzer	1.71 - 1.76
Hydrogen (%)		6.97 - 7.31
Nitrogen (%)		0.01 - 0.03
Sulphur (%)		0%
FFA as oleic (FFA), %	IS 548-1964	10.63 - 11.98
Melting Point (°C)	BDS 908:2001	52 - 56

Table 5: *Rice wax materials (byproduct of RBO) composition.*

Parameters	Method/Instrument	Value
Moisture Content, (%w/w)	IP 2016-65	4.73
Ash Content, (%w/w)	ASTM/IP4/58	48.47
Volatile Matter, (%w/w)	Muffle Furnace	41.48
Fixed Carbon, (%w/w)	Physical	5.32
Higher Calorific Value, kcal/kg	Bomb Calorimeter	3411

Table 6: *Bleaching earth (waste materials of RBO) composition.*

Discussion

Rice bran oil has immense potential as edible oil in Bangladesh since Bangladesh is expected to be the world's fourth largest rice producer in 2017, according to the Crop Prospects and Food Situation report released by the UN's Food and Agriculture Organization [8]. It's necessary to explore diversified use of rice and rice-based products to sustain its productivity in economical scale since only rice production by our farmers is not good enough to make them economical viable. So along with rice production, rice bran, rice bran oil and de-oiled rice bran have value added rice products which might bring economical benefit for all corners related to this rice and rice-based industries in Bangladesh. Rice Bran is a light red covering upper part of the rice under the husk of paddy but it depends on the rice production and proper utilization of rice plant (Paddy) to bring about rice bran. Therefore, it is needed to turn all the manual rice mill to semi auto (introduce rubber roll huller mill in place of engleburg huller mill) and auto mill. Unless measures are taken to increase the domestic production of edible oil out of domestic seeds or Rice Bran, there will be more drainage of foreign currency to meet the increased demand in 2021 [1]. In, Bangladesh, there are three types of rice bran are available such as bran from auto rice mill, bran from semi auto rice mills and bran from engleburg rice bran. In auto rice mill sometimes, silky rice bran is also found in less quantity. RBO industries usually use parboiled rice bran than unparboiled or atop and try to avoid using silky type rice bran since it contains extra moisture and trends to decompose rapidly. In this experiment we also found unparboiled rice bran is not suitable in RBO mills as oil content% remains lower than parboiled rice bran. One of the possibilities behind the reason might be the presence of fraction of starch in unparboiled bran due to milling. The higher the portion of starch in bran, the lower the content of RBO. Similar amount of unparboiled or atop rice produces approximately half the amount of rice bran in parboiled sample (Data not shown). So, it is expected that in unparboiled condition the amount of bran increases due to addition of starch portion from kernel during 10% degree of milling. In crude RBO, for the efficient extraction of quality oil, the interim period between the productions of rice bran and the oil producing industry is a major factor. The mills in Bangladesh have to collect their raw material through the supplier from auto and semi-auto rice mills from different corners of the country. It's a difficult job in this system and it takes more than 5 - 7 days in most of the cases as the mills are not in regular operation. The mills are scattered around the remote corner of the country. So it is also difficult to maintain a continuous supply to run an oil mill smoothly. But it is customary to send rice bran to the oil extraction mill immediate after bran production from rice mill. Otherwise, the quality of oil would be deteriorated due to the hydrolysis activity of enzyme retained in bran. Lipase enzyme produces 10 - 20% FFA in a day and these increases up to 80% in a month [9]. It is recommended that in edible oil, the FFA level should not exceed 3%. It is also recommended that the crude oil for refinement should not contain more than 8% FFA. Our data reveals that untreated rice bran at the 28 day of harvesting bran had grained the highest FFA% and lowest oil % compare to freshly harvested rice bran (Figure 2). On the other hand, heat treated rice bran at the 28 day of harvesting bran had retained similar FFA% and oil % compare to freshly harvested rice bran and performed better than chemically treated bran (Figure 3 and 4). Oil% and FFA% of parboiling milling processed rice bran showed higher value than unparboiled milling processed rice bran at three treatments such as untreated, heat treated and chemically treated (Figure 5-7). Acid Value (as KOH), mg/g, Free Fatty Acid as oleic (FFA)%, Peroxide Value (PV) meq O_2/kg, and Iodine Value (IV) (Hanus method) and oil content % had significant variation among untreated, heat treated and chemically treated treatments at parboiled milling condition but Saponification Value (SV) (as KOH) mg/g, Refractive Index at 40ºC and Relative Density at 300C did not shown any difference (Table 3 and 4). Fatty acid profiling (FAP) of selected treated samples were found mostly similar quality of saturated and unsaturated fatty acids composition between fresh and heat-treated oils. It is further noticeable that heat treated rice bran could produced quality bran oil in respect to FAP and other tested oil chemistry parameters compare to freshly isolated rice bran even after 28 days (Table 4). We did not find the presence of aflatoxins (B1, B2, G1, G2) in crude oil samples (Table 3 and 4) and observed varietal difference in gamma oryzanol concentration as RBO extracted from parboiled BR16 (65.95 mg/g) is significantly higher than BRRI dhan28 (43.43 mg/g).Since we have considered oil content% into account so our research focus was BRRI dhan28 as it produced higher oil content% and lower FFA% than BR16 at parboiled condition (Table 1 and 2). In refining procedure RBO industries usually use bleaching earth which reduces the RBO color but these left unusable at RBO industry promises. Since rice wax materials contained a reasonable portion of free fatty acid as oleic (FFA), % ranges from 10.63-11.98% (Table 5) so, rice wax materials can be used in local soap industries (saponification) along with FFA which is already use in the same soup industries in Bangladesh. In our experiment, we found this bleaching earth might become a source of alternate fueling in brick fields, boiler and potential source of organic matters in soil as volatile matter, (%w/w), ash content (%w/w) and fixed carbon (%w/w) were found at 41.48%, 48.47% and 5.32% respectively (Table 6). In 2012, Amonrat., *et al.* [10] investigated the effect of stabilization of rice bran by domestic heating on mechanical extraction yield, quality and antioxidant properties of cold-pressed RBO and concluded heating could be applied to RBO extraction prior to pressing to improve oil extraction yield, quality and antioxidant properties of cold-pressed RBO. In addition, Ohmic heating (direct electrical resistance heating), external heating such as oven drying (135°C for two hours), steam retorting (121°C and 15 psi for 5 minutes) and internal heating such as micro-wave heating (340 watt, 2450 MHz, 21% moisture, 150 grams bran per batch and 3 min for heating) and irradiation (60Co source with the bran being subjected to 1 megarad) were tried for rice bran stabilization in several studies [11,12]. In our experiment, we found oven heating at 130 - 135°C for two hours of bran treatment suitable and feasible to practice in considering Bangladeshi RBO processing conditions however chemically treated bran stabilization treatment did not work well in terms of nutritional quality in this particular experiment.

Conclusion

Heat treatment at 130 - 135^{0}C for 2 hours, found suitable for stabilizing rice bran from increasing FFA% and lowering oil content % for at least 28 days and it is expected that lipase activity might possibly inhibited or at least show down their activity by heat treatment even though we did not measure lipase activity in this experiment. We would like to recommend heat treatment as physical treatment, soon after harvesting bran from kernel in this regard. This particular physical treatment should be applied in auto rice mill promises soon after harvesting fresh bran. In addition, it is necessary to explore biologically competitive inhibitor of lipase enzyme as an alternative approach which yet to be done. So, there is a huge scope in basic research in this regard. Since RBO industries in Bangladesh, are facing challenges with lack of fresh bran, high FFA% containing bran with lower content oil%, artificial crisis of bran even at harvesting season, so our findings could assist these RBO industries to stabilized rice bran with attainable quality up to 28 days after harvesting bran from rice kernel at parboiled milling condition. Industrial waste such as bleaching earth might have good potential to use as alternate fueling as well as fertilizer in Bangladesh. Soil based experiment should be taken in this regard to assess its potentiality as soil fertilizer.

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Conflict of Interest

Authors do not have any conflict of interest regarding the content of the manuscript.

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