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Effect of Location on Physico-Chemical, Cooking and Antioxidant Properties of Variously-Treated and Milled Indian Rice Cultivars

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Abstract

Rice cultivar, cv.PR-118 was grown in two different locations [abbreviated as cv.PR-118 (Pb.) and cv.PR-118 (Hr.)] and three different milling treatments were given. In the first treatment, the cultivars was normally milled, second treatment involved, parboiling and then milling, third included germination and then milling.These were then studied for the effect of location on their physico-chemical, functional, cooking and antioxidant properties. Flour from cv.PR-118 (Pb.) showed highest bulk density, water and oil absorption capacities as compared to cv. PR-118 (Hr.) for normal, parboiled and germinated samples. Grains from cv.PR-118 (Hr.) took more time to cook as compared to cv.PR-118 (Pb.) for all the treatments. Significant difference ($p<0.05$) was observed in antioxidant activity of cv.PR-118 grown in two locations. cv.PR-118 (Pb.) showed the highest value for $ABTS^+$ scavenging activity as compared to cv.PR-118 (Hr.). In NPR, NBR, PPR and PBR fractions, cv.PR-118 (Hr.) showed higher values(702.3 and 588.2 µg GAE/g, respectively) for total phenolic content. Among GPR fraction, cv.PR-118 (Pb.) showed higher TPC value as compared to cv.PR-118 (Hr.).

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Keywords

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Introduction

Rice (*Oryza sativa* L.) is a major source of carbohydrate in human diet and it's a leading food crop throughout the world. Rice production in India is increased in past few years. Brown rice which is obtained from paddy by dehulling process is a rich source of protein, vitamins and other bioactive compounds. Brown rice (BR) is underutilized because of the presence of bran which affects heat transfer and water absorption, resulting in poor

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cooking quality[1]. Antioxidants in whole grains are major contributor to various health benefits. BR is a rich source of antioxidants, most of which are present in the bran fractions. Lipophilic antioxidants, including vitamin E homologues and δ-oryzanol are abundant in BR and their health benefits has been well documented [2]. Parboiling is a hydrothermal process, which consist soaking, steaming followed by drying. Parboiled rice is dehulled and then generally milled prior to cooking[3]. The parboiling process results in physical, chemical and organoleptic changes in the rice with economic and nutritional advantages[4]. Germination process starts when quiescent dry seed uptake water and stops with emergence of embryonic axis, usually radical[5].

Germination can improve protein content and dietary fiber, reduce sphytic acid and tannin content and mineral bioavailability is enhanced[6]. Genetic and environmental factors, such as locations of crop, time of harvesting and weather conditions are proposed to influence tocols and oryzanol concentration in rice grains[7]. In order to study whether the location affects the properties of rice grains the study was conducted to investigate the effect of location and treatments on physicochemical, cooking and antioxidant properties of same rice cultivar grown in Haryana and Punjab.

Materials and Methods

Materials

Rice cultivar *viz.* PR-118 grown in two different locations in India (Haryana and Punjab) was procured. DPPH, Folin–Ciocalteu reagent, gallic acid, ferulic acid, $K_2S_2O_s$ and ABTS were procured from Sigma-Aldrich (St. Louis, MO, USA). Ferrozine was procured from Himedia Laboratories (Mumbai, India). Methanol, sodium carbonate, sodium nitrite, sodium hydroxide were procured from Central Drug House (New Delhi, India) while aluminium chloride was procured from Fisher Scientific (Mumbai, India).

Parboiling of Paddy

Parboiling of rice was done as per method described by Himmelsbach *et al.,*[8] with slight modifications. Paddy samples (500 g) were soaked in 1lt of water in a water bath with controlled temperature at 60 °C for 6 h. followed by steaming for 8 min. After steaming paddy wasspreadon trays and dried for 12 h in an oven at 40 °C.

Germination of Paddy

Germination was done as per method described by Chung *et al.,*[9] with slight modification. Paddy samples (150 g) were rinsed with water and soaked in 1 liter of deionized water for 24 h at 30 °C. After steeping, excess water was removed, and the paddy was again washed with distilled water. The steeped paddy was subjected to germination in a Humidity chamber (NSW-175, Narang Scientific Works Pvt. Ltd., New Delhi, India) at 30 °C for 72 h after regular interval of 4 h water was sprinkled to control the moisture content in the rice grains. The germinated paddy was then dried for 12 h in oven at 40 °C.

Preparation of Different Fractions

Normal, parboiled and germinated paddy were milled to obtain different fractions. Normal, parboiled and germinated paddy was passed through paddy de-husker (STE-07, Khera Instrument Pvt. Ltd., India) to obtain normal brown rice (NBR), parboiled brown rice (PBR) and germinated brown rice (GBR). Brown rice from normal, parboiled and germinated paddy was then passed through polisher for removal of bran for producing normal polished rice (NPR), parboiled polished rice (PPR) and germinated polished rice (GPR) (Khera Instruments Pvt. Ltd, India). These fractions (brown rice and polished rice) were then collected and ground in a mixer. The flour from these were studied for their functional and antioxidant properties. Head rice was used for studying cooking properties of brown and polished rice.

Cooking Properties of Rice Cultivars

The cooking time, elongation ratio and water uptake ratio of normal, parboiled and germinated rice were determined by method described by Sareepuang *et al.,*[10]. The solid loss during cooking was observedby method described by Thomas *et al.,*[11]

Functional Properties of Rice Flour

The bulk density was determined by following the method's described by Kaur *et al.,*[12] while the water and oil absorption capacities were determined by method as described by Sathe *et al.,*[13]

Antioxidant Activity (AOA)

Antioxidant activity was estimatedby the modified spectroscopic method described by Brand-Williams *et al.,*[15]. Percentage discoloration was calculated by measuring absorbance at 515 nm.

Total Phenolic Content (TPC)

The total phenolic content was estimated by the Folin–Ciocalteu specterophotometric method described by Sharma and *Gujral.,* [16]. The absorbance was measured at 725 nm and results were expressed as µg of gallic acid equivalents (GAE)/ g of sample.

Total Flavonoids Content (TFC)

The TFC was estimated by following the spectrophotometric method given by Jia *et al.,*[17]. Results were expressed as µg catechin equivalents (CE)/g of sample.

Metal Chelating (Fe^{2+}) Activity

The metal chelating activity was estimated by the method of Dinis *et al.,*[18]. The absorbance was measured at 562 nm and results were expressed in percentage metal chelating activity.

Azino-Bis(3-Ethylbenzothiazoline-6-Sulfate) ($ABTS^+$) Scavenging Activity

ABTS scavenging activity was estimated as per method given by Arts *et al.,*[19]. Free radical were produced by reacting ABTS and $K_2S_2O_8$. The ABTS concentration was determined by measuring absorbance at 732 nm.

Statistical Analysis

The data obtained was subjected to one way analysis of variance (ANOVA). The results were expressed as Means (n=3). Standard deviation (SD), linear regression analysis and 95 % confidence intervals were calculated using Microsoft Excel 2007 (Microsoft Corp., Redmond, WA).

Results and Discussion

Functional Properties of Normal, Parboiled and Germinated Flour from Polished and Brown Rice

Bulk density (BD) is reflection of load a sample can carry if allowed to rest directly on another[20]. Bulk density (BD), water absorption capacity (WAC) and oil absorption capacity (OAC) of flours from polished and brown rice was shown in Fig 1. Comparison of flour obtained by milling of polished rice from normal, parboiled and germinated rice for their bulk density, WAC and OAC revealed higher ($p<0.05$) values for cv.PR-118 (Pb.) than cv.PR-118 (Hr.). Similar higher ($p<0.05$) values for flours from normal brown rice, after parboiling and germination were observed for cv.PR-118 (Pb.).

Cooking Properties of Rice Cultivars

During cooking of rice, optimum water uptake ratio, elongation ratio, solid loss and cooking time are important parameters. Cooking properties of rice grown in two different locations after normal milling, parboiling and milling and after germination and milling have been shown in Fig 2. Among both, cv.PR-118 (Hr.) took more time to cook except its parboiled brown rice which shows a reverse. For both, germinated polished rice had significantly ($p<0.05$) lower cooking time. Parboiling resulted in increased cooking time in comparison to normal and germinated counter parts. Water uptake ratio of polished and brown rice from cv.PR-118 (Hr.) for normal, parboiled and germinated rice ranged from 2.1 to 3.4 while for cv.PR-118 (Pb.) the range was from 2.1 to 3.1. Among cv.PR-118 (Hr.), germinated brown rice showed the highest water uptake ratio while the lowest was observed in normal brown rice. Among cv.PR-118 (Pb.), normal polished rice showed the highest value while the lowest was observed in germinated brown rice. Non-significant ($p<0.05$) difference was observed in elongation ratio among cv.PR-118 (Pb.) and cv.PR-118 (Hr.) for normal polished, parboiled polished, germinated polished and germinated brown rice fractions were observed. Elongation ratio, however, was found significantly ($p<0.05$) higher for cv.PR-118 (Pb.) as compared to cv.PR-118 (Hr.). Solid loss is an important parameter to determine the quality of rice. Rice obtained after germination and polishing from cv.PR-118 (Pb.) had significantly ($p<0.05$) higher solid loss than cv.PR-118 (Hr.).

Antioxidant Activity (AOA)

The antioxidant properties of cv.PR-118 grown at two different locations was shown in Table 1. The cv. PR-118 (Pb.) showed higher values as compared to cv.PR-118 (Hr.) for polished rice fractions of normal, parboiled and germinated rice. The antioxidant activity of polished rice fractions of normal, parboiled and germinated rice for cv.PR-118 (Pb.) ranged from 3.6 to 8.2 % while for cv.PR-118 (Hr.) the range was from 2.7 to 6.0 %. cv.PR-118 (Pb.) showed higher values of antioxidant activity for brown rice (11.2 %) as compared to cv.PR-118 (Hr.). In comparison to cv.PR-118 (Pb.), the antioxidant activity of parboiled and germinated brown rice fractions were observed higher for cv.PR- 118 (Hr.) (5.5 and 10.5 %, respectively). For bran fractions, cv.PR-118 (Pb.) showed higher values for bran and parboiled rice bran fractions (62.7 and 21.3 %, respectively) as compared to cv.PR-118 (Hr.). According to Klepacka *et al.,*[21] antioxidant content and TPC depends on various factors including variety, location and environmental factors. Arya *et al.,*[22] reported that concentration of phenolic compounds, which are produces by plants for different functions, might be the major contributor to the antioxidant activity.

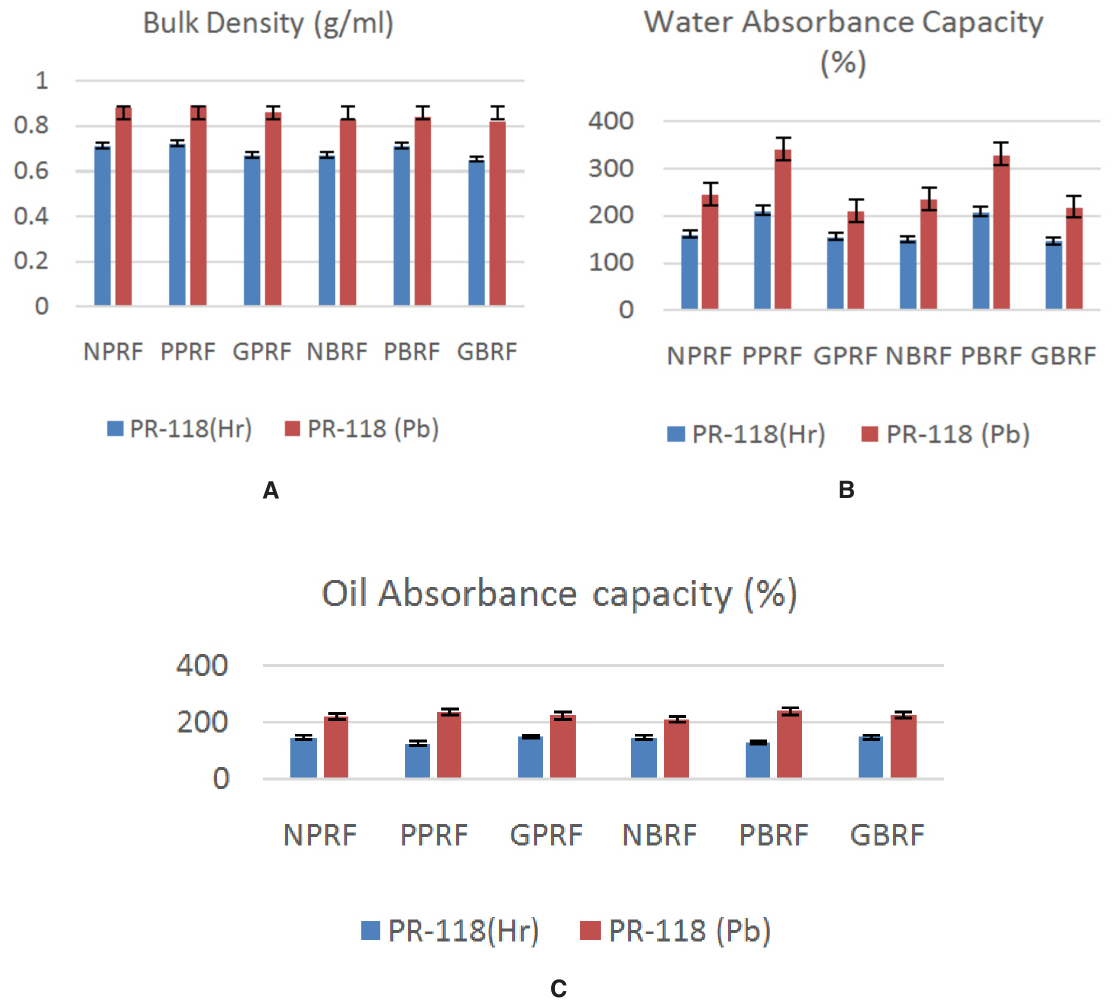

Fig.1: Effect of location on Bulk density (A), water absorption capacity (B) and oil absorption capacity (C) of different rice cultivars

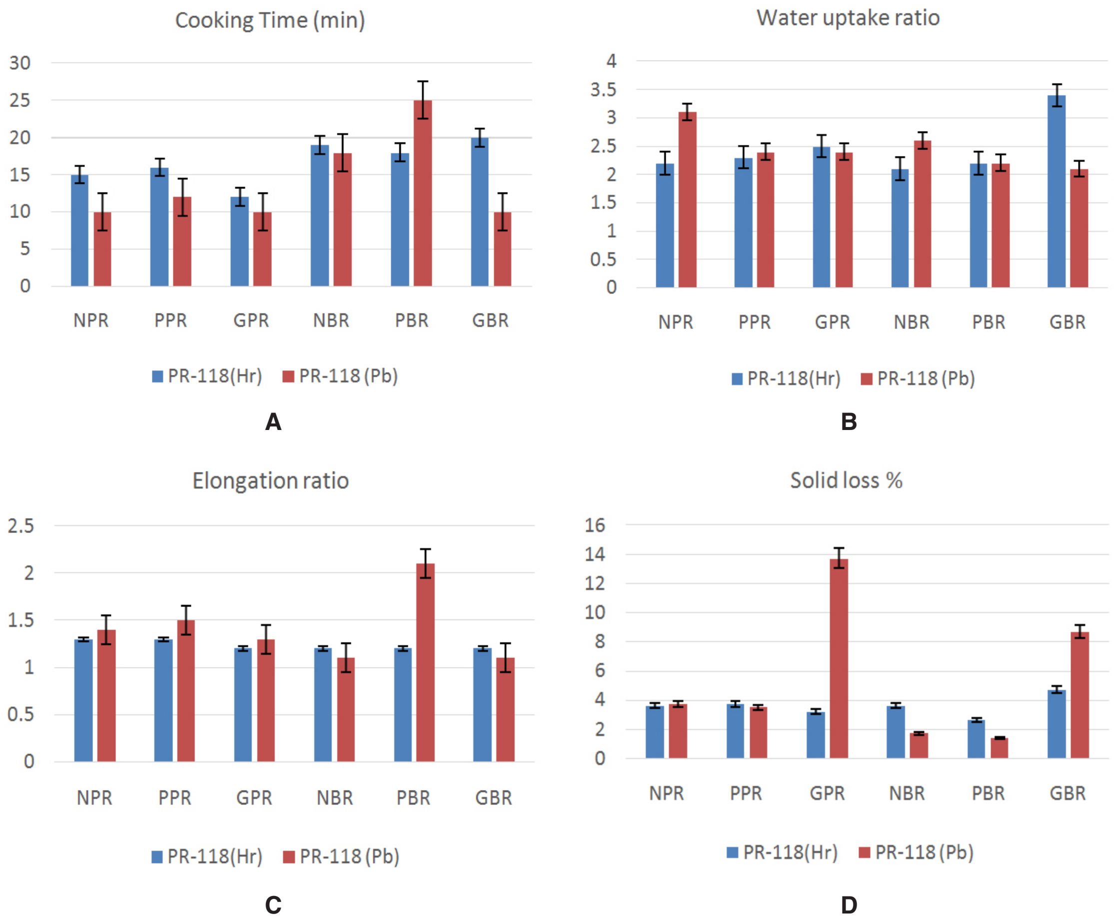

Fig.2: Effect of location on Cooking time (A), water uptake ratio (B) and elongation ratio (C) and solid loss (D) of different rice cultivars

Metal Chelating (Fe^{2+}) Activity (MCA)

The metal chelating activity of cv.PR-118 grown at two different locations was reported in Table 1. The metal chelating activity for polished, parboiled polished and germinated polished rice fractions were observed higher for cv.PR-118 (Pb.) as compared to cv.PR-118 (Hr.). For brown rice cv.PR-118 (Hr.) showed the higher value for antioxidant activity as compared to cv.PR-118 (Pb.). The parboiling and germination, however, resulted in higher value for brown rice fractions of cv.PR-118 (Pb.). For bran fractions, the metal chelating activity of bran from cv.PR-118 (Hr.) showed higher value of 81.5 % as compared to cv.PR-118 (Pb.) (32.7 %).

$ABTS^+$ Scavenging Activity

The $ABTS^+$ scavenging activity of cv.PR-118 (Pb.) showed significantly ($p<0.05$) higher value than cv.PR-118 (Hr.) for polished rice, brown rice and bran fractions (Table 1). The parboiling and germination also resulted in higher values for $ABTS^+$ scavenging activity for cv.PR-118 (Pb.) as compared to cv.PR-118 (Hr.). In cv.PR-118 (Pb.), the values for $ABTS^+$ scavenging activity after germination and polishing resulted in higher value (53.2 %). Similarly, in brown rice germination treatment resulted in increased $ABTS^+$ scavenging activity (63.5 %). In bran, both parboiling and germination resulted in decreased $ABTS^+$ scavenging activity in both cv.PR-118 (Hr.) and cv.PR-118 (Pb.). Latiff *et al.,* [23] also reported difference in $ABTS^+$ scavenging activity in the rice cultivars grown at different location.

Table 1: Effect of location on antioxidant activity, metal chelating activity and ABTS scavenging activity of different fractions of rice cultivars

	Antioxidant activity (%)		Metal chelating activity (%)		ABTS scavenging activity (%)	
	PR-118 (Hr.)	PR-118 (Pb.)	PR-118 (Hr.)	PR-118 (Pb.)	PR-118 (Hr.)	PR-118 (Pb.)
Normal Polished rice	4.0±0.45[a]	6.1±0.30[b]	5.5±0.47[a]	9.8±0.26[b]	9.5±0.35[a]	13.7±0.25[b]
Parboiled Polished rice	2.7±0.60[a]	3.6±0.25[b]	4.4±0.21[a]	65.6±0.25[b]	4.6±0.15[a]	12.5±0.35[b]
Germinated Polished rice	6.0±0.65[a]	8.2±0.35[b]	38.1±0.15[a]	72.2±0.55[b]	8.4±0.55[a]	53.2±0.60[b]
Brown rice	4.7±0.49[a]	11.2±0.51[b]	19.8±0.45[b]	14.6±0.35[a]	9.6±0.25[a]	19.9±0.45[b]
Parboiled Brown rice	5.5±0.15[b]	3.6±0.11[a]	10.6±0.25[a]	28.0±0.31[b]	5.9±0.42[a]	17.7±0.21[b]
Germinated Brown rice	10.5±0.05[b]	9.1±0.30[a]	50.7±0.15[a]	71.1±0.55[b]	11.3±0.45[a]	63.5±0.26[b]
Bran	41.4±0.22[a]	62.7±0.34[b]	81.5±0.60[b]	32.7±0.40[a]	28±0.65[a]	98.2±0.55[b]
Parboiled rice bran	16.5±0.30[a]	21.3±0.35[b]	9.5±0.30[a]	--	12.8±0.21[a]	34.9±0.56[b]
Germinated rice bran	39.1±0.55[b]	23.2±0.55[a]	63.7±0.25[a]	76.1±0.55[b]	26.7±0.30[a]	88.1±0.45[b]

Data are presented as mean± SD (n=3)

[a-b] Means with same superscript (lowercase) in a row for a particular property do not vary significantly (p<0.05) from each other

Table 2: Effect of location on total phenolic content and total flavonoids content of different fractions of rice cultivars

	Total phenolic content (µg GAE/g)		Total flavonoids content (µg CE/g)	
	PR-118 (Hr.)	PR-118 (Pb.)	PR-118 (Hr.)	PR-118 (Pb.)
Polished rice	702±0.45[b]	329±0.35[a]	664±0.26[b]	143±0.35[a]
Parboiled Polished rice	588±0.31[b]	483±0.40[a]	410±0.36[b]	136±0.35[a]
Germinated Polished rice	784±0.36[a]	1908±0.35[b]	976±0.11[b]	176±0.15[a]
Brown rice	3040±0.75[b]	842±0.51[a]	1376±0.55[b]	863±0.40[a]
Parboiled Brown rice	2711±0.35[b]	640±0.66[a]	750±0.60[b]	250±0.35[a]
Germinated Brown rice	1404±0.35[a]	2040±0.45[b]	1356±0.36[b]	530±0.40[a]
Bran	6715±0.35[b]	6162±0.35[a]	7902±0.70[b]	4603±0.37[a]
Parboiled rice bran	3250±0.30[b]	2364±0.30[a]	2730±0.75[a]	4436±0.15[b]
Germinated rice bran	4241±0.15[b]	3838±0.35[a]	4110±0.30[b]	1543±0.40[a]

Data are presented as mean± SD (n=3)

[a-b] Means with same superscript (lowercase) in a row for a particular property do not vary significantly (p<0.05) from each other

Total Phenolic Content (TPC)

The total phenolic content of cv.PR-118 grown at two different locations is shown in Table 2. The polished and parboiled rice fraction of cv.PR-118 (Hr.) showed higher values (702.3 and 588.2 µg GAE/g, respectively) than cv.PR-118 (Pb.). However, germinated polished rice fraction of cv.PR-118 (Pb.) had higher value than cv.PR-118 (Hr.). Among brown rice fractions, cv.PR-118 (Hr.)showed higher values for TPC for brown and parboiled brown rice fractions (3040 and 2711 μgGAE/gm, respectively). The reverse was, however, observed for germinated brown rice, with cv.PR-118 (Pb.) showing higher value than cv.PR-118 (Hr.). In bran fractions, cv.PR-118 (Hr.) showed higher values for total phenolic content in bran, parboiled bran and germinated bran rice fractions. Arya *et al.,* [22] reported that the geographical regions, genotypes, solvents and their interaction affect the TPC and TAC of *Rumex patientia* L. in the trans-Himalaya. Mpofu *et al.,* [24] reported variations in concentration of phenolic acid concentrations of 6 wheat genotypes produced in Canada at four different locations and reported that environmental conditions effected greater than genotypic variations.

Total Flavonoids Content (TFC)

The total flavonoids content of cv.PR-118grown at two different locations was reported in Table 2. For polished and parboiled polished rice fractions, cv.PR-118 (Hr.) showed the higher value the cv.PR-118 (Pb.). Brown rice and parboiled brown rice from cv.PR-118 (Hr.) had higher values for TFC while cv.PR-118 (Pb.) had higher values for germinated brown rice. Among bran fractions, cv.PR-118 (Hr.) showed higher values for TFC in bran and germinated brown rice fractions (7902 and 1543 μg CE/g, respectively).However, in parboiled rice bran fraction higher value was observed for cv.PR-118 (Pb.). According to Latiff *et al.,*[23] the difference in flavonoids content in rice cultivars may be due to phenolic content in the rice grain.

Conclusions

Growing location influenced physico-chemical as well as antioxidant properties of rice cv.PR-118. Comparison of BD, WAC and OAC of flour from polished and brown rice fraction of normal, parboiled and germinated revealed higher values for cv.PR-118 (Pb.) than cv.PR-118 (Hr.). Among both cultivars cv.PR-118 (Hr.) took more time to cook except its parboiled brown rice which shows a reverse. Rice obtained after germination and polishing from cv.PR-118 (Pb.) had significantly ($p<0.05$) higher solid loss than cv.PR-118 (Hr.). The AOA, MCA and $ABTS^+$ scavenging activity for cv.PR-118(Pb.) showed higher value in its normal, parboiled and germinated polished rice fractions. The TPC and TFC of polished and parboiled rice fractions of cv.PR-118 (Hr.) showed higher value than cv.PR-118 (Pb.).

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Conflict of Interest

There is no conflict of interest

References

1. Charoenthaikij P, Jangchud K, Jangchud A, Piyachomkwan K, Tungtrakul P, Prinyawiwatkul W. Germination conditions affect physicochemical properties of germinated brown rice flour. *Journal of Food Science; **74***: 658–665:(2009)
2. Esa N.M, Ling T.B, Peng L.S. By-products of Rice Processing: An Overview of Health Benefits and Applications. *Rice Research; **1***(1): 1-11:(2013)
3. Min B, McClung A, Chen M-H. Effect of hydrothermal processes on antioxidants in brown, purple and red bran whole grain rice (*Oryza sativa* L.). *Food Chemistry*; ***159***: 106-115:(2014)
4. Kale S.J, Jha S.K, Jha G.K, Sinha J.P, Lal S.B. Soaking induced changes in chemical composition, glycemic index and starch characteristics of basmati rice. *Rice Science; **22***(5): 227-236: (2015)
5. Bewley J.D, Bradford K, Hilhorst H. Seeds: Physiology of development, germination and dormancy. Springer Science and Business Media, 3rd edition, pp.133 (2012)
6. GhavidelR.A,Prakash J. The impact of germination and dehulling on nutrients, antinutrients, in vitro iron and calcium bioavailability and in vitro starch and protein digestibility of some legume seeds. *LWT-Food Science and Technology; **40***(7): 1292-1299: (2007)
7. Aguilar-Garcia C, Gavino G, Baragario-

Mosqueda M, Hevia P, Gavino V.C. Correlation of tocopherol, tocotrienol, γ-oryzanol and total polyphenol content in rice bran with different antioxidant capacity assays. *Food Chemistry;* ***102***: 1228-1232: (2007)

8. Himmelsbach D.S, Manful J.T, Coker R.D. Changes in rice with variable temperature parboiling: Thermal and Spectroscopic Assessment. *Cereal Chemistry;* ***85***(3): 384-390: (2008)
9. Chung H, Cho A, Lim S. Effect of heat-moisture treatment for utilization of germinated brown rice in wheat noodle. *LWT - Food Science and Technology;**47***: 342–347:(2012)
10. Sarrepuang K, Siriamornpun S, Wiset L, Meesa, N. Effect of soaking temperature on physical, chemical and cooking properties of parboiled fragrant rice. *World Journal of Agricultural Sciences;* ***4***(4): 409-415: (2008)
11. Thomas R, Wan-Nadiah W.A, Bhatt, R. Physiochemical properties, proximate composition and cooking qualities of locally grown and imports rice varieties marketed in Penang, Malaysia. *International Food Research Journal;* ***20***(3), 1345-1351: (2013)
12. Kaur M, Kaushal P, Sandhu K.S. Studies on physicochemical and pasting properties of taro (*Colocasiaesculenta* L.) flour in comparison with a cereal, tuber and legume flour. *Journal of Food Science and Technology;* ***50***(1): 94-100: (2013)
13. Sathe S.K, Deshpande S.S, Salunkhe D.K. Functional properties of winged bean proteins. *Journal of Food Science;* ***47***: 503-508: (1982)
14. ThoryR,Sandhu K.S. A comparison of mango kernel starch with a novel starch from litchi (Litchi chinesis) kernel: Physicochemical, morphological, pasting and rheological properties. *International Journal of Food Properties;* ***20***(4): 911-921: (2017)
15. Brand-Williams W, Cuvelier M.E, Berset C. Use of a free radical method to evaluate antioxidant activity. *Lebensmittel-Wissenschaft und Technologie;* ***28***: 245-251:(1995)
16. Sharma P,Gujral H.S. Antioxidant and polyphenols oxidase activity of germinated barley and its milling fractions. *Food Chemistry;* ***120***: 673-678: (2010)
17. Jia Z, Tang M, Wu J. The determination of flavonoids content in mulberry and their scavenging effects on superoxides radicals. *Food Chemistry;* ***64***: 555-559:(1998)
18. Dinis T.C.P, Madeira V.M.C, Almeidam L.M. Action of phenolic derivates (acetoaminophen, salycilate, and 5-aminosalycilate) as inhibitors of membrane lipid peroxidation and peroxylradicals scavengers. *Archives of Biochemistry and Biophysics;* ***315***: 161-169:(1994)
19. Arts M.J.T.J, Haenen G.R.M.M, VossH.P,Bast, A. Antioxidant capacity of reaction products limits the applicability of the Trolox equivalent antioxidant capacity (TEAC) assay. *Food and Chemical Toxicology;* ***42***: 45-49:(2004)
20. Onimawo I.A, Asugo A. Effect of germination on the nutrient content and functional properties of pigeon pea flour. *Journal of Food Science and Technology;* ***41***, 170-174:(2004)
21. Klepacka J, GujskaE,Michalak J. Phenolic compound as cultivar and variety distinguishing factor in some plant products. *Plant Food Human Nutrition;* ***66***:64-69: (2011)
22. Arya J.S, Singh N, Rinchen T, Maurya S.B,Korekar G. Genotype, geographical regions and solvents dependent antioxidant activity of *Rumexpatientia* L. in cold desert of trans-Himalaya Ladhak, India. *Australian Journal of Crop Science;* ***9***(2): 98-104: (2015)
23. Latiff N.A, Alam S.A.Z, Hanapi S.Z, Supari N., Javed M.A, Tin L.C,Sarmidi M.R. Evaluation of antioxidant activity and total polyphenols content on upland rice. *Journal of Natural Product Plant Resources;* ***7***(2): 1-6:(2017)
24. Mpofu A, Sapirstein H.D, Beta T. Genotype and environmental variation in phenolic content, phenolic acid composition and antioxidant activity of hard spring wheat. *Journal of Agricultural Food Chemistry;* ***54***:1265-1270: (2006).