8. Steiner, A. K. *et al.*, Quantification of structural uncertainty in climate data records from GPS radio occultation. *Atmos. Chem. Phys. Discuss.*, 2013, **12**, 26963–26994.
9. Harnisch, F., Healy, S. B., Bauer, P. and English, S. J., Scaling of GNSS radio occultation impact with observation number using an ensemble of data assimilations. *Mon. Weather Rev.*, 2013, **141**, 4395–4413; doi:10.1029/2008GL035873.
10. Healy, S. B. and Thepaut, J. N., Assimilation experiments with CHAMP GPS radio occultation measurements. *Q. J. R. Meteorol. Soc.*, 2006, **132**, 605–623.
11. Aparicio, J. and Deblonde, G., Impact of the assimilation of CHAMP refractivity profiles in environment Canada global forecasts. *Mon. Weather Rev.*, 2008, **136**, 257–275.
12. Poli, P., Healy, S., Rabier, F. and Pailleux, J., Preliminary assessment of the scalability of GPS radio occultations impact in numerical weather prediction. *Geophys. Res. Lett.*, 2008, **35**(23), L23 811.
13. Cucurull, L., Improvement in the use of an operational constellation of GPS radio occultation receivers in weather forecasting. *Weather Forecast.*, 2010, **25**, 749–767.
14. Cucurull, L., Kuo, Y. H., Barker, D. and Rizvi, S. R. H., Assessing the impact of simulated COSMIC GPS radio occultation data on weather analysis over the Antarctic: A case study. *Mon. Weather Rev.*, 2006, **134**, 3283–3296.
15. Auligne, T., McNally, A. and Dee, D., Adaptive bias correction for satellite data in a numerical weather prediction system. *Q. J. R. Meteorol. Soc.*, 2007, **133**, 631–642.
16. Cardinali, C. and Healy, S., Impact of GPS radio occultation measurements in the ECMWF system using adjoint-based diagnostics. *Q. J. R. Meteorol. Soc.*, 2014, **140**, 2315–2320.
17. Cucurull, L. and Derber, J. C., Operational implementation of COSMIC observations into NCEP's global data assimilation system. *Weather Forecast.*, 2007, **23**, 702–711.
18. Johny, C. J. and Prasad, V. S., Impact of assimilation of Megha-Tropiques ROSA radio occultation refractivity by observing system simulation experiment. *Curr. Sci.*, 2014, **106**(9), 1297–1305.
19. Sokolovskiy, S., Effect of super-refraction on inversions of radio occultation signals in the lower troposphere. *Radio Sci.*, 2003, **38**, 1058; doi:10.1029/2002ES002728.
20. Cucurull, L., Derber, J. C. and Purser, R. J., A bending angle forward operator for global positioning system radio occultation measurements. *J. Geophys. Res. Atmos.*, 2013, **118**, 14–28; 2012JD017782.
21. Prasad, V. S., Saji, M., Gupta, M. D., Rajagopal, E. N. and Dutta, S. K., Implementation of upgraded global forecasting systems (T382L64 and T574L64) at NCMRWF. Technical Report. 2011, NCMR/TR/5/2011.
22. Hu, M., Shao, H., Stark, D. and Newman, K., Gridpoint Statistical Interpolation (GSI; Version 3.3 User's Guide). Developmental Testbed Centre, NCAR, NOAA, USA, 2014; http://www.dtcenter.org/com-GSI/users/index.php

ACKNOWLEDGEMENTS. We thank the Space Applications Centre (SAC), Ahmedabad for providing the data. We also thank V. Manavala Ramanujam and Jignesh Kshatriya for fruitful discussions. We thank the Head, NCMRWF for support.

Received 5 July 2017; accepted 15 October 2017

doi: 10.18520/cs/v114/i05/1083-1088

Comparative analysis of grain quality and nutraceutical properties of selected rice varieties from Kerala

K. S. Shylaraj*, Soumya G. Nadh and Shimi K. Chandran

Rice Research Station, Kerala Agricultural University, Kochi 682 019, India

Kerala, the land of rich biodiversity, is a treasure of land races of many crops. The speciality rice varieties of Kerala include Pokkali (organic rice), Jeerakasala and Gandhakasala (scented rice varieties), Black Njavara and Golden Njavara (medicinal rice varieties). A study on the nutraceutical properties of these speciality rice varieties was made to understand their health benefits. Oil content in the rice bran and antioxidants like oryzanol, tocopherol and tocotrienol in the rice bran oil (RBO) of these rice varieties were estimated and compared apart from the quality and nutritional analysis of both rice and bran. The study revealed that the bran is rich in RBO and antioxidants like oryzanol, tocopherol and tocotrienol which may contribute to its high therapeutic value. The study recommends minimum polishing of these rice varieties during milling for consumption purpose. As the bran is rich in fibre and micronutrients like Fe, Cu, B and S, it should be utilized for the preparation of value-added products like biscuits, baby foods, breads, etc. for healthy human consumption. The study envisages an urgent need for the utilization of the huge quantity of rice bran oil and as component of other food products.

Keywords: Antioxidants, grain quality, nutraceutical property, rice varieties.

RICE is the most important tropical cereal and staple food of about half the human population in the world. Starch constitutes the bulk of rice grain and it contains amylose and amylopectin. The human body can digest and absorb the carbohydrates in rice relatively quickly. The protein content of rice is lower than that of wheat, but is of superior quality and utilized better by the body than wheat protein. It contains all the eight essential amino acids in delicately balanced proportion[1].

Rice bran, the brown outer layer of the rice kernel is mainly composed of pericarp, aleurone/sub-aleurone layers and germ. Currently, it is discarded as waste product during the process of rice milling in this part of the world[2]. Godber *et al.*[3] have shown that rice bran and rice bran oil (RBO) have potential health benefits in the prevention of diseases such as cancer, kidney stones, heart diseases and hyperlipidaemia. This is attributed to the

*For correspondence. (e-mail: shylarajks@gmail.com)

high content of gamma oryzanol, which is a mixture of ferulate esters of triterpene alcohols[3].

Kerala was once a rich treasure of diverse land races/ varieties, but the well-known genetic diversity of rice in Kerala has been lost due to the advent of modern rice varieties. 'Navara' (Njavara) is a unique medicinal rice of Kerala extensively used in the *Ayurvedic* system of medicine. Two ecotypes of Njavara, viz. black glumed Njavara type and yellow glumed Njavara type are being cultivated. Gandhakasala and Jeerakasala are the most famous indigenous scented varieties of Wayanad district, Kerala[4]. Pokkali is the world-famous saline tolerant organic rice of Kerala; it has some medicinal value and has a special taste. The objective of the present study is to understand the nutraceutical properties and health benefits of these speciality rice varieties of Kerala in comparison with the saline-tolerant landrace Pokkali.

Rice samples of five specialty rice varieties of Kerala, viz. Pokkali, Black Njavara, Golden Njavara, Jeerakasala and Gandhakasala, and two widely cultivated rice varieties, viz. Jyothi and Uma were used for the study. Studies on the nutraceutical properties of Black Njavara, Golden Njavara, Jyothi, Uma and Jaya have been carried out earlier[5–9]. The seeds of Pokkali were collected from the Rice Research Station, Vyttila; Jyothi was sourced from Regional Agricultural Research Station, Pattambi; Uma, Black Njavara and Golden Njavara from Rice Research Station, Moncompu and Jeerakasala and Gandhakasala were obtained from Regional Agricultural Research Station, Ambalavayal. Freshly milled bran samples were collected from a local rice mill, followed by sieving to separate grain from bran and stored in air-tight polyethylene bags at 20°C in a deep freezer.

Grain-size and shape were determined using linear scale and the grains were classified according to their size and shape. Based on length/breadth (L/B) ratio, the grains were classified into long slender (LS), short slender (SS), medium slender (MS), long bold (LB) and short bold (SB)[10].

Spectrometric determination of amylose was done by taking 100 mg of well-powdered milled rice and adding 1 ml 95% (v/v) ethanol and 9 ml 1 N NaOH. Samples were heated for 10 min in boiling water bath and then cooled and volume was made up to 100 ml. Next 5 ml sample suspension was diluted to 100 ml after acidifying with 1 N acetic acid and 1 ml iodine solution. After 20 min absorbance was determined at 620 nm. A series of standards with known amylose content were prepared and a standard curve was plotted. The amylose content of the test samples was determined from the standard curve and calculated on fresh-weight basis[11].

The bran and grain samples were dried at 105°C in moisture cups for 6–8 h; drying was continued until a constant weight was obtained according to American Oil Chemists[1] Society (AOCS) Ca 2C-25 standard[12] and moisture content was calculated as percentage.

Dehusked kernels were placed in petri plates and spaced evenly so as to allow enough spreading. After adding 1.7% KOH, the samples were incubated overnight at 30°C. Gelatinization temperature was noted based on the rate of spreading of kernels. This value determines the cooking temperature of rice varieties[10].

Fibre extraction was conducted as outlined by the American Association of Cereal Chemists standard[13]. Defatted rice husk was digested using 1.25% H_2SO_4. Filtration of five sample was continued by washing with water and 1.25% NaOH. Then samples were washed with 1.25% H_2SO_4 and ethanol. The residue was dried (105°C) in a hot-air oven and weighed (a). Then the residue was incinerated in a muffle furnace, maintained at 550°C for 5 h and weighed (b). The difference between (a) and (b) gave the fibre content.

The protein content in each sample was estimated by biuret method[14]. Protein was estimated by grinding 100 mg of rice sample with 100 ml trichloroacetic acid. After centrigufation, 0.1 N NaOH was added to the supernatant. The sample was kept at room temperature for 30 min after adding 2 ml distilled water and 3 ml biuret reagent. Absorbance was measured at 540 nm, and a series of known protein concentrations were prepared and a standard curve was plotted.

The AOCS standard was used to estimate fatty acid composition of RBO.

Micronutrients (Fe, Zn, Mn and Cu) and macronutrients (Ca, Mg) contents of grain samples were estimated using an atomic absorption spectrophotometer (novAA300). The macronutrient potassium was estimated using flame photometer, whereas boron, sulphur and phosphorus were estimated using a spectrophotometer.

The air-dried bran (500 g) was fed to Soxhlet exactor fitted with a 2 l round-bottom flask and a condenser. The extraction was executed on a water bath for 6 h with 1.5 l of hexane. The solvent was distilled under vacuum in a rotary evaporator[16].

The oryzanol content of RBO was estimated using AOCS standard[17]. For this, 10 mg of the oil was dissolved in hexane and the optical density was recorded at 314 nm in a double-beam recording spectrophotometer (UV-240; Shimadzu, Japan). The concentration of oryzanol was determined using its extinction coefficient value of 358.9.

The composition of tocopherols and tocotrienols of the oil samples was determined using AOCS standard[18] and by high performance liquid chromatography (model LC-10AVP; Shimadzu, Japan) fitted with a silica column (CLC-SIL(M) 250 mm × 4.6 mm) and fluorescence detector. The mobile phase was hexane isopropanol (99.5 : 0.5, v/v) at a flow rate of 1 ml/min, and excitation and emission wavelengths of 290 and 330 nm respectively.

Statistical significance of the data obtained was analysed by one-way analysis of variance followed by using Web based Agricultural Statistics Software Package

Table 1. Grain appearance of selected rice varieties

	Unhusked		Husked				
Variety	Length (L, mm)	Width (B, mm)	Length (mm)	Width (mm)	*L*/*B* ratio	Grain type/size	Grain shape
Pokkali	9.3[a]	3.4[a]	6.6[a]	2.6	2.53	Medium	Intermediate
Black Njavara	8.0[bc]	3.0[b]	6.0[b]	2.0	3.0	Medium	Intermediate
Golden Njavara	8.0[bc]	3.0[b]	6.0[b]	2.0	3.0	Medium	Intermediate
Jyothi	9.1[a]	3.0[b]	7.06[a]	2.26	3.12	Long	Slender
Uma	8.06[b]	3.1[ab]	5.84[b]	2.44	2.39	Medium	Intermediate
Jeerakasala	7.7[c]	2.4[c]	5.98[b]	2.2	2.71	Medium	Intermediate
Gandhakasala	6.2[d]	2.3[c]	4.6[c]	2.04	2.25	Short	Intermediate
CD Value	0.337	0.360	0.663				

Means with the same letters do not differ significantly at $P < 0.05$.

Table 2. Grain quality parameters of selected rice varieties

Variety	Amylose content (%)	Gelatinization temperature	Moisture content (%)	Fibre content (%) Grain	Fibre content (%) Bran	Protein content (%)
Pokkali	24	Intermediate	12.77	0.46[a]	23[c]	7.77
Black Njavara	25	Intermediate	12.09	0.35[b]	22[c]	7.16
Golden Njavara	25	Intermediate	12.66	0.35[b]	31[ab]	7.25
Jyothi	25	Intermediate	12.56	0.47[a]	27[abc]	7.33
Uma	25	Intermediate	12.58	0.30[bc]	26[bc]	7.61
Jeerakasala	25	Intermediate	12.65	0.22[d]	26[bc]	7.63
Gandhakasala	24	Intermediate	12.21	0.23[cd]	32[a]	7.00
CD Value				0.073	5.406	

Means with the same letters do not differ significantly at $P < 0.05$.

(WASP 2.0) designed and developed by Central Coastal Agricultural Research Institute (ICAR), Goa (www.ccari.res.in/waspnew.html).

Grain-size and shape of rice are important characteristics which determine the consumer preference as well as commercial success of a variety[9]. The grain size and shape of Pokkali, Black Njavara, Golden Njavara, Jeerakasala and Uma belonged to medium intermediate group, Jyothi belonged to long slender group and Gandhakasala to short intermediate group (Table 1). According to Oghbaei and Prakash[19], length/breath (*L*/*B*) ratio denotes the shape and size of a grain. In our study, there were no significant differences in the *L*/*B* ratio for Black Njavara, Golden Njavara and Jyothi. Comparatively highest *L*/*B* ratio was recorded for Jyothi and lowest for Gandhakasala (Table 1). Pokkali had comparatively higher L/B ratio compared to rice varieties of Uma and Gandhakasala.

Amylose content can play a significant role in determining the overall cooking, eating and pasting properties of a rice variety[20,21]. Most consumers prefer rice with intermediate AC ranging between 20% and 25%. All rice varieties in the present study belonged to the intermediate amylose content group ranging from 24% to 25% (Table 2), with Pokkali and Gandhakasala showing 24% intermediate amylose content. Thus Pokkali falls under the intermediate amylose content group along with other well-known rice varieties in the present study.

The gelatinization temperature (GT) of rice samples has been classified as high to intermediate, which indicates that the temperature required for normal cooking time is 75–79°C (ref. 22). While the gelatinization of rice samples is 65–70 mm and categorized as soft, this indicates the tendency of cooked rice to be soft on cooling[22]. The speciality rice varieties in this study belonged to two GT groups (Table 2). Pokkali, Jyothi, Uma, Black Njavara and Golden Njavara belonged to intermediate GT group (requires 50–69°C for cooking), whereas Jeerakasala and Gandhakasala belonged to low intermediate GT group (requires less than 50°C for cooking).

Moisture content of rice is an important factor which markedly affects rice quality, especially shelf-life and milling quality[9]. The results of the present study showed that moisture content of different rice varieties ranged between 12.09% and 12.77% (Table 2). In this study, the organic rice variety Pokkali recorded high moisture percentage of 12.77 followed by Golden Njavara (12.66).

Although fibre remains an important constituent of food, it cannot be considered as an essential nutrient. Fibre reduces the risk of bowel disorders and fights constipation[23]. Tomlin and Read[24], Burton *et al.*[25] suggested the use of rice bran for enrichment of nutraceutical foods. The crude fibre content of various tested rice grain varieties ranged between 0.22% and 0.47% (Table 2). Jyothi was found to have the highest fibre content of rice grain

Table 3. Mineral content of rice grain

Variety	P (%)	K (%)	Ca (%)	Mg (%)	Fe (mg/kg)	Zn (mg/kg)	Mn (mg/kg)	Cu (mg/kg)	B (mg/kg)	S (mg/kg)
Pokkali	0.003	0.17	0.05	0.03	25.0^{a}	22.6^{a}	20.4^{a}	1.4^{d}	76.7^{a}	0.03
Black Njavara	0.003	0.11	0.03	0.02	14.2^{b}	12.6^{b}	13.2^{b}	1.4^{d}	38.3^{cd}	0.06
Golden Njavara	0.003	0.19	0.02	0.03	28.8^{a}	14.4^{b}	19.4^{a}	8.6^{c}	56.7^{b}	0.06
Jyothi	0.001	0.06	0.07	0.02	16.8^{b}	13.0^{b}	7.2^{c}	0.3^{d}	25.3^{d}	0.02
Uma	0.003	0.15	0.05	0.02	11.2^{b}	12.2^{b}	13.0^{b}	0.8^{d}	35.0^{cd}	0.03
Jeerakasala	0.002	0.13	0.08	0.03	16.0^{b}	13.0^{b}	3.8^{d}	22.4^{a}	76.7^{a}	0.06
Gandhakasala	0.001	0.11	0.06	0.02	10.4^{b}	13.8^{b}	1.4^{d}	14.2^{b}	41.7^{c}	0.07
Optimum value	0.20	0.30	0.05	0.20	10-15	20.0	50.0	10.0	50.0	0.10
CD Value					7.812	3.916	2.961	2.862	14.289	

Means with the same letters do not differ significantly at $P < 0.05$.

Table 4. Mineral content of rice bran

Variety	P (%)	K (%)	Ca (%)	Mg (%)	Fe (mg/kg)	Zn (mg/kg)	Mn (mg/kg)	Cu (mg/kg)	B (mg/kg)	S (mg/kg)
Pokkali	0.02	0.81	0.01^{c}	0.03	568.8^{a}	62.8^{a}	142.4^{c}	3.4^{de}	58.33^{d}	0.13
Black Njavara	0.02	0.76	0.04^{ab}	0.02	379^{b}	68^{a}	143.6^{c}	2.5^{e}	31.67^{e}	0.09
Golden Njavara	0.02	0.83	0.05^{a}	0.03	238^{d}	46.4^{bc}	152.2^{b}	8.6^{a}	71.67^{c}	0.05
Jyothi	0.02	0.81	0.01^{c}	0.03	148.8^{e}	49.8^{b}	69.2^{d}	3.4^{de}	36.67^{e}	0.01
Uma	0.02	0.84	0.01^{c}	0.03	142.2^{e}	45.8^{bc}	65.4^{d}	4.4^{cd}	90.00^{b}	0.13
Jeerakasala	0.02	0.86	0.02^{bc}	0.03	251.4^{c}	41.2^{cd}	140.8^{c}	4.8^{bc}	140.0^{a}	0.01
Gandhakasala	0.03	1.07	0.02^{bc}	0.03	386.6^{a}	39^{d}	200^{a}	5.8^{b}	63.33^{d}	0.02
CD value			0.021		13.400	5.327	7.264	1.317	6.856	

Means with the same letters do not differ significantly at $P < 0.0$.

(0.47%) followed by Pokkali (0.46%). There were no significant differences in the fibre content of grain for Black Njavara (0.35%), Golden Njavara (0.35%) and Uma (0.30%). Among the varieties, lowest ratio was recorded for Jeerakasala and Gandhakasala (0.22% and 0.23% respectively). The fibre content of rice bran of different rice varieties ranged between 22% and 32% (Table 2). Gandhakasala had the highest fibre content of rice bran (32%) followed by Golden Njavara (31%), whereas Jeerakasala, Uma and Jyothi had 26%, 26% and 27% fibre content respectively. Black Njavara and Pokkali showed 22% and 23% of fibre content of rice bran respectively. This suggests that rice bran is a good fibre source that can be added to various food products.

The rice protein is unique in its properties, i.e. it is rich in essential amino acids like lysine. Further, the rice protein is easily digestible (>90% digestibility) compared to wheat protein. Many researchers have reported variability of protein content in different varieties of rice up to 15% (refs 26–28). The present study showed that protein content of the tested rice varieties ranged from 7.16% to 7.77% (Table 2), which is the normal range. Pokkali showed the highest protein content (7.77%) followed by Jeerakasala (7.63%). There was no significant difference in the protein content of selected rice varieties.

Table 3 shows the mineral content in milled rice of the varieties in the present study. Rice is not a rich source of minerals. The milled rice grains of all the varieties were found to be deficient in P (%), K (%), Mn (mg/kg) and S (mg/kg) content. Maximum Fe content was present in Golden Njavara (28.8 mg/kg) followed by Pokkali (25 mg/kg), which is about double the optimum value. Jeerakasala and Pokkali contained maximum B content (76.7 mg/kg), which is about 50% higher than the optimum value.

Table 4 shows the mineral content of rice bran of the test rice varieties. Though rice is not a rich source of minerals, the available minerals are mainly present in the bran which will be lost while milling. The rice bran of Pokkali is rich in Fe content (568.8 mg/kg), which is about four times more than the popular varieties Jyothi and Uma. The bran of Black Njavara and Gandhakasala is also rich in Fe content, which is about 2.8 times higher than that of the check varieties Uma and Jyothi. The bran of the Gandhakasala is rich in Mn content (200 mg/kg), which is about three times higher than the check varieties followed by Njavara, Pokkali and Jeerakasala. Golden Njavara is a rich source of Cu (8.6 mg/kg), which is about 2.5 times higher than the check varieties. Jeerakasala is a rich source of B (140 mg/kg), which is about three times higher than that of the check variety Jyothi followed by Uma. The bran of Pokkali and Uma is rich in S content (0.13 mg/kg).

The hexane extracted oil content of different varieties of rice in this study varied from 5.15% to 10.05% (Table 5). Black Njavara had the highest bran oil content (10.05%) followed by Pokkali (9.18%). Minor variation in the oil content within a country may be attributed to

Figure 1. *a*, Jyothi; *b*, Jaya; *c*, Uma; (*d*) Pokkali; *e*, Jeerakasala; *f*, Gandhakasala; *g*, Golden Njavara; *h*, Black Njavara.

Table 5. Oil and antioxidant content of selected rice varieties

Variety	Oil content (%)	Oryzanol content (mg/100 g oil)	Tocopherol content (mg/100 g oil)	Tocotrienol content (mg/100 g oil)
Pokkali	9.18[ab]	2230 ± 5[b]	24.86[d]	56.45[b]
Black Njavara	10.05[a]	2050 ± 50[d]	25.42[cd]	61.0[b]
Golden Njavara	5.27[cd]	2340 ± 20[a]	29.42[c]	57.04[b]
Jyothi	5.26[cd]	1980 ± 50[e]	6.90[e]	34.82[c]
Uma	5.15[d]	1750 ± 40[f]	7.53[e]	19.15[d]
Jeerakasala	5.25[cd]	2150 ± 5[c]	51.06[b]	80.32[a]
Gandhakasala	7.47[bc]	2040 ± 20[d]	70.45[a]	58.82[b]
CD value	2.247	12.967	4.355	5.427

Means with the same letters do not differ significantly at $P < 0.05$.

Table 6. Fatty acid content of RBO of selected rice varieties

Variety	SFA (mg/100 g oil)	MUFA (mg/100 g oil)	PUFA (mg/100 g oil)
Pokkali	21.1	47.4	31.5
Black Njavara	23.1	44.3	32.4
Golden Njavara	21.4	47.2	31.3
Jyothi	20.8	45.8	33.3
Uma	24.6	45.9	30.4
Jeerakasala	19.6	48.0	32.5
Gandhakasala	20.1	47.9	31.8

the possible change in environmental and geological conditions of the regions[29].

The medicinal value of RBO is due to the presence of significantly high amounts of antioxidants such as oryzanol, tocopherol and tocotrienol (Table 5). The oryzanol content in the bran oil of the rice varieties under study ranged from 1750 to 2340 mg/100 g oil. The maximum oryzanol content was recorded by the bran oil of Golden Njavara (2340 mg/100 g oil) followed by Pokkali (2230 mg/100g oil). This is 18% higher than that of the popular variety Jyothi and 34% higher than that of the check variety Uma. Oryzanol is composed of several kinds of ferulic acids and has an effect similar to that of vitamin E in accelerating human growth, facilitating blood circulation and stimulating hormonal secretion[30]. It is also effective in treating a broad range of gastrointestinal disorders, including stress-induced gastric and duodenal ulcers[31,32].

Tocopherols and tocotrienols are the vitamin E analogues present in RBO. Generally, RBO contains more tocotrienols than tocopherols. These are natural lipid-soluble antioxidants and potent free-radical scavengers present in RBO. The main biochemical function of tocopherols is considered to be the protection of consumed polyunsaturated fatty acids (PUFA) against peroxidation[33]. The tocopherol content in the different rice varieties ranged from 6.90 to 70.45 mg/100 g oil (Table 5). Gandhakasala had the highest amount of tocopherol

(70.45%), which is about nine times higher than the check varieties Jyothi and Uma, followed by the variety Jeerakasala (51.06 mg/100 g oil).

Tocotrienols have been claimed to give protection against heart attack due to their anti-thrombotic properties and greater antioxidant potential than the tocopherols[34]. The tocotrienol content of the rice varieties under study ranged from 19.15 to 80.32 mg/100 g oil (Table 5). The highest value was recorded by RBO of Jeerakasala (80.32 mg/100 mg oil), which is about four times higher than the check variety Uma and two times higher than Jyothi. Pokkali also had comparatively higher amount of oryzanol (2230 mg/100 g oil), tocopherol (24.86 mg/100 g oil) and tocotrienol (56.45 mg/100 g oil), almost on par with the medicinal rice variety Njavara (black and golden ecotypes).

Table 6 shows the fatty acid composition of RBO of different rice varieties. The investigated oils were found to contain saturated fatty acid (SFA), monounsaturated fatty acid (MUFA) and PUFA contents ranging from 19.6% to 24.6%, 44.3% to 48.0% and 30.4% to 33.3% respectively. Rice fibre and RBO have potential uses as natural additives to enhance oxidative stability during storage and to reduce the SFA/unsaturated fatty acid ratio and cholesterol content of several domestic food items[35]. The Japan Ministry of Health and Welfare suggests a ratio of 1 : 1.5 : 1 for saturated/monosaturated/polyunsaturated fatty acids for healthy edible oils[16]. The fatty acid composition of the studied RBO from Kerala falls under the above recommendations and contains high ratio of MUFA to SFA. It appears that RBO is almost equal to peanut oil in supplying fatty acid requirements (SFA, MUFA and PUFA). Hence, RBO can be used as a substitute for peanut oil for human consumption.

This study has revealed that Pokkali rice had relatively higher protein, along with minerals such as Mn (%), B (%) and P (%) in rice grain whereas higher levels of Mg (%), Fe (%), Zn (%) and S (%) are obtained in rice bran compared to the other rice varieties. Based on the observed data, Pokkali also contains all the desired qualities at par with the other superior speciality rice varieties under study. The results of this study highlight the importance of nutraceutical properties in Pokkali. This would add value to the product for international acceptance and pave the way for export of this rice. It will further enhance the price of this rice, which will help in the revival of Pokkali cultivation. The study also emphasizes the need for proper utilization of the huge quantity of rice bran produced as agricultural waste during milling as bran oil for human consumption. Further, based on the present study, minimum polishing is recommended during milling for consumption purpose and proper utilization of the antioxidant-rich bran of these speciality rice varieties in the preparation of healthy snacks such as biscuits, baby foods, breads, etc. for human consumption.

1. www.westonaprice.org/health-topics/...nutrition/protein-building-blocks-of-the-body/.
2. Michael, O. A., Dick, I. G. and Bibiana, D. I., Physico-chemical and sensory evaluation of wheat bread supplemented with stabilized undefatted rice bran, *Food Nutr. Sci.*, 2013, 43–48.
3. Godber, J., Xu, Z., Hegsted, D. and Walker, T., Rice and rice bran oil in functional foods development. *Louisiana Agric*., 2002, 9–10.
4. Raman Kutty, N. N. and Bhaskaran, U. P., Jeerakashala – a tall scented rice variety in Kerala, India, IRRN, 1979, 6–7.
5. Akiri Rao, S. V. C., Sareddy Reddy, G., Phanithi Babu, P. and Attipalli Reddy, R., The antioxidant and antiproliferative activities of methanolic extracts from Njavara rice bran. *BMC Compl. Alternat. Med*., 2010, **10**, 4.
6. Deepa, G., Venkatachalam, L., Bhagyalakshmi, N., Shashidhar, H. E., Vasudeva Singh and Akhilender Naidu, Physico chemical and genetic analysis of an endemic rice variety, Njavara (*Oryza sativa* L.) in comparison to two popular South Indian Cultivars, Jyothi (PTB 39) and IR 64. *J. Agric. Food Chem.*, 2009, **7**, 11476–11483.
7. Mohanlal, S., Parvathy, R. and Shalini, V., Helen, A. and Jayalekshmy, A., Isolation, Characterization and quantification of Tricin and flavonolignans in the medicinal rice Njavara (*Oryza sativa* L.), as compared to staple Varieties. *Plant Foods Hum. Nutr.*, 2011, **66**(1), 91–96.
8. Parvathy, R., Mohanlal, S., Pushpam, C., Helen, A. and Jayalekshmy, A., Antioxidant properties, anti-inflammatory effects and bioactive constituents of the Indian medicinal rice Njavara yellow compared with staple varieties. *Food Sci. Biotechnol.*, 2014.
9. Reshmi, R. and Nandini, P. V., Nutrient composition and physico-chemical properties of medicinal rice – Njavara. *Asian J. Home Sci.*, 2012, **7**, 211–215.
10. IRRI, Annual Report for 1967, International Rice Research Institute, Los Banos, Philippines, 1968, p. 308.
11. Ashish, J. *et al.*, Effects of cooking on amylose content of rice. *Eur. J. Exp. Biol.*, 2012, **2**(2), 385–388.
12. AOCS, *Official Method and Recommended Practices of the American Oil Chemists, Society*, AOCS Press, Champaign, IL, USA, 5th edn, 2000.
13. AACC, *Approved Method of the American Association of Cereal Chemists*, St. Paul, MN, USA, Vol. 2, 10th edn, 2000.
14. Harod, V., *Textbook of Practical Clinical Biochemistry*, 1988, 6th edn, pp. 448–449.
15. AOCS, *Official and Tentative Method of the AOCS* (ed. Firestone, D.), American Oil Chemists' Society, Champaign, IL, USA, 1993, 4th edn.
16. Farooq, A., Tabreez, A. and Zahid, M., Methodical characterization of rice (*Oryza sativa*) bran oil from Pakistan, *Grasas Aceites*, 2005, Vol. 56, pp. 125–134.
17. AOCS, Official and Tentative Method, American Oil Chemists, Society, 2006, pp. 117–120.
18. AOCS, Official and Tentative Method, American Oil Chemists (ed. Firestone, D.), Society, Champaign, IL, USA, 1998.
19. Oghbaei, M. and Prakash, J., Effect of cooking on nutritional quality of raw and parboiled rice. *Indian J. Nutr. Diet*, 2012, **47**(5), 188–199.
20. Adu-Kwarteng, E., Ellis, W. O., Oduro, I. and Manful, J. T., Rice grain quality: a comparison of local varieties with new varieties under study in Ghana. *Food Control*, 2003, 507–514.
21. Asghar, S., Anjum, F. M., Amir, M. R. and Khan, M. A., Cooking and eating characteristics of rice (*Oryza sativa* L.). *Pak. J. Food Sci.*, 2012, 128–132.
22. Shilpa, J. and Sellappan, K., Grain quality evaluation of traditionally cultivated rice varieties of Goa, India. *Recent Res. Sci. Technol.*, 2010, **2**(6), 88–97.
23. Food and Agriculture Organization/World Health Organization, Obesity: preventing and managing global epidemic, WHO technical report, Geneva, Switzerland, 1998, pp. 11–12.

24. Tomlin, J. and Read, N. W., A comparative study of the effects on colon function caused by feeding ispaghula husk and polydextrose. *Aliment. Pharmacol. Therapeut.*, 1988, **2**(6), 513–519.
25. Burton, G. W., Traber, M. G., Acuff, R. V., Walters, D. N., Kayden, H., Hughes L. and Ingold, K. U., Human plasma and tissue alpha-tocopherol concentrations in response to Supplementation with deuterated natural and synthetic vitamin E. *Am. J. Clin. Nutr.*, 1998, **67**(4), 669–684.
26. Sotelo, A. V., Saisa, I., Montolvo, Hernandez, M. and Hernandez, L., Aragon, chemical composition of different fractions of 12 Mexican varieties of rice obtained during milling. *Cereal Chem.*, 1990, 209–212.
27. Lam-Sanchez, A., Santos, J. E., Takamura, K., Treptow, R. M. O. and Oliveira, J. E. D., Estudosnutricionais com arroz (*Oryza sativa*, L.). *Aliment. Nutr.*, 1993, **5**, 37–48.
28. Kennedy, G. and Burlingame, B., Analysis of food composition data on rice from a geneticre source perspective. *Food Chem.*, 2003, **80**, 589–596.
29. Ibrahim, S. S., Ismail, M., Samuel, G., Kamal, E. and Azhari, E. l., Benseed: a potential oil source. *Agric. Res. Rev.*, 1994, **52**, 47–50.
30. Rong, N., Ausman, L. M. and Nicolosi, R. J., Oryzanol decreases cholesterol absorption and aortic fatty steaks in hamsters. *Lipids*, 1997, 303–309.
31. Rukhmini, C. and Raghuram, T. C., Nutritional and biochemical aspects of the hypolipidimic action of rice bran oil. A review. *J. Am. Coll. Nutr.*, 1991, **10**, 366–375.
32. Rukmani, C., Nutritional significance of rice bran oil. *Indian J. Med. Res.*, 1995, **102**, 241–244.
33. Kamal-Eldin, A. and Andersson, R., A multivariate study of the correlation between tocopherol content and fatty acid composition in vegetable oils. *J. Am. Oil Chem. Soc*., 1997, **74**, 375–380.
34. Rossell, J. B., Analysis and properties of oilseeds. In *Analysis of Oilseeds, Fats and Fatty Foods* (eds Rossell, J. B. and Pritchard, J. L. R.), Elsevier Applied Science, New York, USA, 1991, pp. 80–98.
35. Kim, H., Lee, S., Park, K. and Hong, I., Characterization of extraction and separation of rice bran oil rich in EFA using SFE process. *Sep. Purif. Technol.*, 1999, **15**, 1–8.

ACKNOWLEDGEMENTS. We thank the Rashtriya Krishi Vikas Yojana, Government of India for financial support to carry out this study. We also acknowledge the analytical services rendered by the Central Food Technological Research Institute, Mysore, an NABL accredited laboratory.

Received 14 October 2015; revised accepted 10 October 2017

doi: 10.18520/cs/v114/i05/1088-1094

Dynamics of shifting cultivation in relation to slope and elevation in parts of Nagaland, India

Jenita Mary Nongkynrih*, Chwadaka Pohshna and Kamani Kanta Sarma

North Eastern Space Applications Centre, Umiam 793 103, India

Shifting cultivation in North Eastern Region of India is practised along the hill slopes by tribes of the region for subsistence living. The present study was carried out to examine the dynamics of shifting cultivation in relation to slope and elevation in Mokokchung, Teunsang and Wokha districts of Nagaland. Temporal Advanced Widefield Sensor data of Resources I were used to derive information on the changes and spatial extent of shifting cultivation areas in these districts. Slope and elevation parameters were derived from Shuttle Radar Thematic Mapper data. The study found a change in current shifting cultivation lands to regenerating shifting cultivation. All three districts showed an increasing trend in regenerating shifting cultivation and decrease in current shifting cultivation lands. A shift of cultivation plots towards higher elevations was noted. Southern slopes are mostly occupied for shifting cultivation by tribal communities in these areas.

Keywords: Remote sensing, slope, shifting cultivation.

SHIFTING cultivation is an old agricultural system in which plots of land, mainly in slopes, are cultivated temporarily. After losing fertility the plots are left for natural regeneration. Majority of the hill tribes of North Eastern Region (NER) in India practise shifting cultivation along hill slopes. Synonyms of shifting cultivation include terms like swidden[1], cut-and-burn, land rotation, and slash and burn. The widespread practice of shifting cultivation is regionally known as *Jhum* cultivation[2] and locally by different names among different tribes inhabiting the region.

Shifting cultivation is considered a strategy of resource management in which fields are shifted to exploit the energy and nutrient capital of the vegetation–soil complex of the future site[3]. It is a form of land use characterized by an alternation between a short span of cultivation and a comparatively long span of natural or improved fallow[4]. This cultivation is also referred to as an adaptive forest management practice in which hill and mountain lands are productively utilized as well as forest, soil and water resources are conserved. It is ecologically preferable to alternative agricultural and forestry activities[5]. Shifting of fields is cyclical and rotational. The fields are prepared by removal of the fallow vegetation normally (though not

*For correspondence. (e-mail: jnongkynrih@nesac.gov.in)