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Effect of Processing on the Nutritional Quality of Red Rice Cultivars

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ABSTRACT Red rice also known as "weedy rice" is the species of rice (*oryza)*. It is low yielding rice variety with red pericarp, which is an unmilled variety with nutty flavor. Rice with a red bran layer is called red rice. In the present study an attempt was made to see the effect of dehulling and milling on the physical and nutritional quality of red rice cultivars. Five cultivars of red rice viz *Sukara, Roda dhan, Desi dhan, Jatto* and *Chohatto* were procured and were analyzed for their physical and nutritional quality after processing that is dehulling and milling. Physical characteristics analyzed were color, size density and bulk density. For nutritional quality evaluation these samples were analyzed for their proximate composition, starch, total carbohydrates, calorific value, non- protein nitrogen (NPN), true protein, free fatty acids and free amino acid content by using standard methods. Results revealed that rice recovery of dehulled rice was higher as compared to milled rice. Husk recovery and broken rice recovery was on the contrary higher after milling as compared to dehulling The milling of red rice cultivars showed a significant ($p \leq 0.05$) decrease in grain size and proximate composition whereas density, bulk density, total carbohydrates and starch content increased. The minimum NPN content was in milled grains and maximum was in dehulled rice grains. Milling resulted in a decrease in true protein, free fatty acid and free amino acid content significantly ($P \leq 0.05$). Dehulling is a better processing technique for retaining the nutrients in red rice cultivars as compared to milling.

INTRODUCTION

Rice (*Oryza sativa* L.) is the seed of a monocot plant of family *Oryza*. As a cereal grain, it is the most important staple food for a large part of the world's population, especially in East, South, Southeast Asia, Middle East, Latin America and the West Indies. It is one of the leading food crops of the world and is second only to wheat in terms of annual production for food use. Rice varieties probably emerged 10,000 to 15,000 years ago along with southern and northern slopes of Himalayas. They withstood the periods of drought and pronounced variations in temperature and later spread from Himalayas to northeast and eastern India, Southeast Asia and south China. States in northwest Himalayas like Himachal Pradesh, Uttarakhand and Jammu and Kashmir have great diversity of traditional rice genotypes (Sharma 1998). In the traditional growing areas of Asia, rice of various colors *viz*. red, purple, black, brown, yellow, and green have been known and grown, but for the present-day generation, rice denotes only pearly white grain. The name of rice refers to the kernel color (black, red or purple), which is formed by deposits of anthocyanins in different layers of the pericarp, seed coat and aleurone (Chaudhary 2003). Rice with a red bran layer is called red rice. Though the color of rice is confined to the bran layer, a tinge of red remains even after a high degree of milling of the rice. The color of the bran ranges from light to dark red. The bran layer contains polyphenols, anthocyanins and possesses antioxidant properties. The inner portion of red and white rice is alike and white in color. Red rice also known as "weedy rice" is the species of rice (*oryza)*. It is low yielding rice variety with red pericarp, which is an unmilled variety with nutty flavor. Red rice has a number of nutritional advantages over common rice. It contains higher content of protein, vitamins and minerals. The zinc and iron content of red rice is 2-3 times higher than that of white rice, although the iron content varies with cultivar and production location. Nutritional quality of rice has received more attention in the developing countries, where monotonous consumption of rice may lead to deficiencies of essential minerals, vitamins, and other nutritional compositions (Bouis et al. 2003). This is not caused by nutritional deficiency in rice grain itself, but is due to its being eaten in the form of the milled white kernel. Milling of the red rice removes bran layer, which is rich in protein, fiber, oil, minerals, vitamins, and other phy-

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tochemicals, leading to loss of most of these nutritional components of the rice grain after milling. Work has been done on the effect of processing on the nutritional quality of white rice but much work has not been done on the effect of dehulling and milling on the nutritional and physical characteristics of red rice.

The present study was planned with the objective of analyzing the effect of two different proceeding techniques, that is, dehulling and milling on the physical and nutritional quality of red rice cultivars grown in Himachal Pradesh.

MATERIAL AND METHODS

Five genotypes of red rice *viz.Sukara, Roda dhan, Desi dhan, Jatto and Chohatto* were procured from Rice Research Station Malan (CSKHPAU Palampur India). All the samples were cleaned manually to remove the adhering dirt and other foreign materials. The procured samples of red rice were divided into two lots. One lot was only dehulled with mechanical dehuller available at the Wheat and Rice Research Station, Malan CSKHPKV Palampur, Himachal Pradesh (H.P.), and other lot was dehulled and then milled locally in a rice milling unit. The samples of red rice were grounded to a fine powder separately with the help of stainless steel grinder and were stored in airtight containers so as to prevent changes till further analysis was completed.

The whole grains were observed for their physical characteristics viz color, size (length and breadth by using vernier caliper), density and bulk density. For estimating density one thousand seeds in triplicate from each genotype were weighed and put in graduated cylinder containing known quantity of water and rise in water level was noted. Density was calculated by the following formula:

Density = W (g)/V (ml)

Where, W = Weight of 1000 seeds and V= Rise in water level after adding seeds.

The bulk density was measured according to the method given by Narain et al. (1978). The porosity was calculated by the formula:

Porosity percent = Density – Bulk Density/ DensityX100

Moisture, ash, crude fat and crude fiber contents in the rice samples was analyzed using AOAC (1990) methods. Nitrogen was analyzed by the Micro-Kjeldhal method and was multiplied by the factor of 5.95 for converting it in to crude protein (AOAC 1990). Non Protein Nitrogen (NPN) in rice samples was determined by the method of Pellet and Young (1980). Difference between crude protein nitrogen and non-protein nitrogen multiplied by factor 5.95 gave true protein.

Total carbohydrates were calculated by the formula:

Total carbohydrate percent = 100 - (Moisture + crude ash + crude protein + crude fat + crude fiber)

Starch in the samples was determined by the method of Clegg (1956). Energy in the samples was determined by chromic oxide method of O'shea and Maguire (1962). Free fatty acid in the samples was determined according to the method given by AACC (1990). Free amino acid in the samples was determined by the method given by Lie (1973).

Statistical Analysis

The experiments were carried out in triplicate and the data so obtained was subjected to Analysis of Variance (ANOVA) using statistical package Analysis Of Variance in Completely Randomized Factorial Design (AVCRFD). The obtained data was interpreted following Sendecor and Cochran (1994).

RESULTS AND DISCUSSION

Milling Characteristics

The milling characteristics of paddy are important from the standpoint of rice quality and are directly related to the milling capabilities, that is, amount of rice, husk and brokens to rice. The milling quality of rice is considered to be better if it gives more of whole kernels and less of brokens during milling. From the economic point of view, brokens not only lower the market valve but also lead to physical losses, which lower the total milling turnout. As is clear from the data in Table 1 that rice recovery after dehulling was higher as compared to rice recovery after milling. Husk recovery and broken rice recovery was on the contrary higher in milling as compared to dehulling of paddy because during milling the aleurone layer of rice grain is also lost. Similar results have been reported by Bal et al. (1995) and Singh et al. (1996). The rice recovery after dehulling and milling amongst different genotypes varied significantly ($P \leq 0.05$). The dehulled paddy gave a higher yield and lower husk content as compared to milled paddy (Table 1). Singh (1996) reported that the husk content of indicia and japonica genotypes of raw rice was found in the range of 17.67 to 21.33 percent. The slight variation in the results of present study might be due to varietal differences. The broken percent rice recovery of different genotypes varied significantly ($P \leq 0.05$) when compared with each other and also a significant difference was observed when different treatments of genotypes were compared with each other. This might be due to varietal differences and agro-climatically conditions under which these genotypes were cultivated. The broken rice percent ranged from 11.51 to 25.68 percent in dehulled paddy and it was 16.48 to 36.13 percent in milled paddy. Similar results have also been reported by Singh (1996). This might have been due to the technique of processing, as grain is less exposed to rollers as compared to milling.

Dehulling is better than the milling of paddy for the simple reason that brokens tend to reduce the quality and marketability of the rice grains. It also involves screening for separation of brokens as prevalent today. Although ready market is available for brokens, particularly of the long grain, scented rice genotypes, yet the price fetched by such grains is negligible as compared to the whole grain.

The milling and dehulling of red rice cultivars affected the physical parameters viz. grain length, breadth, 1000-grain weight and porosity whereas, density and bulk density showed significant increase due to removal of bran layer. Maximum grain breadth was present in dehulled red rice grains (Table 2). It is clear from the data 1000-grain weight of dehulled red rice varieties was higher than 1000-grain weight of milled red rice varieties. As it is clearly depicted from the data, highest 1000-grain weight was there in dehulled *Chohatto* (24.96g) and lowest was in milled *Desi dhan* (19.96g). A non-significant difference in the grain porosity was there in the

Table 1: Effect of processing on rice recovery, husk and broken rice

	Rice recovery percent		*Husk percent*		*Broken rice percent*	
Genotype	*T1**	*T2***	*T1**	*T2***	*T1**	*T2***
Jatto	81.81	79.4	18.19	20.6	20.02	34.77
Desi dhan	80.05	78.67	19.95	21.33	18.8	23.9
Sukara	80.55	78.87	19.45	21.13	25.68	36.13
Roda dhan	83.53	80.27	16.47	19.47	11.51	16.48
Chohatto	82.14	80.4	17.86	19.47	16.43	21.81
CD($p \leq 0.05$)						
Processing	0.43		0.49		0.51	
Genotypes	0.19		0.37		0.23	

Table 2: Effect of processing on physical characteristics of red rice genotypes

Parameter/	*Jatto*		*Desi dhan*		*Sukara*		*Roda dhan*		*Chohatto*		*CD ($p<0.05$)*
Variety	*T1**	*T2***	*T1**	*T2***	*T1**	*T2***	*T1**	*T2***	*T1**	*T2***	
Colour	Reddish brown	Creamish with red trace	Reddish-brown	White with red traces	Reddish -orange	White with red traces	Reddish	White with red traces	Reddish orange	Creamish	
Size											
Length (mm)	5.7	5.3	4.8	4.6	5	4.63	5.2	4.97	5.93	5.33	0.04
Breadth (mm)	2.5	2.3	1.9	1.8	2.5	2.4	2	1.9	2.63	2.47	0.03
Weight (g) 1000-seeds	21.67	20.7	18.87	17.84	24.87	23.14	21.48	19.96	24.96	23.19	0.02
Density (g/ml)	1.35	1.32	1.33	1.32	1.4	1.39	1.34	1.33	1.31	1.31	0.11
Bulk Density (g/ml)	0.91	0.9	0.88	0.88	0.89	0.88	0.89	0.89	0.88	0.87	0.12
Porosity percent	35.79	35.62	35.16	34.07	36.99	36.93	34.4	34.22	32.27	30.61	1.32

*T1- Dehulling, **T2- Milling Data presented is mean of ten determinations.

dehulled and milled the grain. The porosity percent of different genotype under study varied none significantly (P≤0.05) and ranged from 30.61 to 36.93 percent. The decrease in grain breadth during milling might have been due to the reason that milling removes the outer layer of rice grain. Singh (1996) also reported similar results in hand-pounded and machine-milled raw rice. Much difference was not there in the bulk density. Deepa et al. in 2008 reported that that grain length ranged between 6.63mm to 6.93mm, grain breadth ranged between 2.13mm to 2.52mm and the length to breadth ratio ranged from 2.65 to 3.26 in two red rice and brown rice cultivars. Eighteen rice cultivars were studied by Yafang et al. (2011) and he found that grain length ranged from 3.28mm to 7.55mm, grain breadth ranged between 2.31mm to 3.24mm and length to breadth ratio ranged from 1.15 g to 2.54 g. Variation in these parameters was observed among different cultivars. These changes might have been due to removal of bran.

Moisture content of dehulled red rice varieties of viz. *Jatto*, *Desi dhan*, *Sukara*, *Roda dhan* and *Chohatto* was 12.41, 12.33, 12.51, 12.35 and 11.95 percent, whereas for milled rice grains of above varieties it was 12.36, 12.04, 12.52, 12.73 and 12.143 percent. Similar results were reported by Fatema et al. (2010) for moisture content of three common rice varieties of Bangladesh that is BR-14, BR-29 and BR-44 with the value of 12.77, 13.45 and 11.20 percent, respectively. This variation in the results might be due to grain characteristics like hygroscopic properties of different cultivars, which plays important role in gaining moisture. Nine red rice genotypes and three black rice cultivars were analyzed for the moisture content by Sompong et al. (2011). The values of the red rice genotypes ranged from 9.28 to 13.12 percent and of the black rice cultivars ranged from 11.26 to 12.59 percent.

As it is clearly depicted from the data (Table 3) maximum ash content was observed in dehulled *Desi dhan* (1.66%) and minimum was in milled *Chohatto* cultivar (0.59%). A significant (P≤0.05) difference was observed in ash content of dehulled and milled red rice cultivars when compared with each other. The reason for the decrease of ash content due to milling might be removal of germ layer, which is rich in minerals whereas mineral content was reduced during milling. The cultivars understudy also varied significantly (P≤0.05) with respect to ash content. The maximum ash content was reported in *Desi dhan* dehulled (1.66%) and minimum in *Chohatto* milled (0.59%). The varietal differences were observed among the different genotypes. Singh (1996) while studying the quality characteristics of nine rice genotypes grown in Himachal Pradesh reported that machine milling decreased the ash content from 1.21 percent to 0.78 percent.

As is clear from the data in Table 3 crude fat, crude protein and crude fiber content was higher in the dehulled red rice cultivars. A significant (P≤0.05) difference in these parameters was observed in between the dehulled and milled rice when compared which each other. As it is clear from the data that the total carbohydrate content increased after milling due to the fact that there was no effect on the endosperm of the grain and carbohydrate is present in endosperm. The maximum total carbohydrate content in dehulled red rice genotypes was recorded in *Desi dhan* (76.04%), which significantly (P≤0.05) increased to 77.39 percent after milling. Similar results were also recorded in the other genotypes

Table 3: Effect of milling on proximate composition of red rice varieties

Parameter/	*Jatto*		*Desi dhan*		*Sukara*		*Roda dhan*		*Chohatto*		*CD (p<0.05)*
Variety	*T1**	*T2***	*T1**	*T2***	*T1**	*T2***	*T1**	*T2***	*T1**	*T2***	
Moisture percent	12.41	12.36	12.33	12.04	12.51	12.52	12.35	12.3	11.95	12.36	0.17
Ash percent	1.39	1.16	1.66	1.09	1.07	0.65	1.24	0.64	1.11	0.59	0.06
Crude fat percent	2	1.38	1.35	1.26	1.49	0.98	1.75	1.44	2.12	1.67	0.08
Crude Protein percent	8.49	8.23	8.62	8.16	10.53	9.79	9.79	9.56	9.92	9.76	0.11
Crude fibre percent	1.91	0.85	1.73	0.69	1.19	0.49	1.42	0.66	1.17	0.65	0.72
Total carbohydrates percent	75.71	76.89	76.04	77.39	74.4	76.06	74.92	75.88	75.56	76.93	0.12

*T1- Dehulling, **T2- Milling

of red rice. The minimum total carbohydrate content was recorded in *Sukara* (74.40%), which after milling increased to 76.06 percent. Meena et al. (2009) recorded the total carbohydrate content of rice was in the range of 74.35 to 80.43 percent. The variations in the results could be attributed to the fact that carbohydrate is mainly distributed in the endosperm of the grain, which is not much affected during the milling process. The variation in the total carbohydrate content could also be due to varietal characteristics.

The milled red rice genotypes had significantly (P≤0.05) higher starch content as compared to their dehulled counterparts. A non-significant (P≤ 0.05) difference was observed between dehulled forms of *Jatto* and *Desi dhan*. A non-significant (P≤ 0.05) difference was also observed between dehulled and milled forms of *Sukara* and *Roda dhan* but a significant (P≤ 0.05) difference was observed between the genotypes when compared with each other (Table 4). As is clear from the data that the starch content increased after milling might be due to the increase in carbohydrate content, which might be due to decrease in other nutrient constituents.

The starch content of dehulled red rice was in the range of 73.38 to 76.79 percent, while in milled red rice genotypes it was found to be in the range of 74.36 to 81.69 percent. Singh et al. (1998) while studying the effect of milling of rice on the nutritive and consumer properties of rice also reported an increase in the starch content. The variation in the concentration of starch in milled red rice could be attributed to the fact that starch is mainly distributed in the endosperm of the grain, which is not much affected by the milling of grain. The energy content of milled red rice genotypes was significantly (P≤ 0.05) lower than dehulled red rice genotypes. A significant (P≤ 0.05) difference was observed in the dehulled and milled *Jatto*, milled *Desi dhan*, *dehulled Sukara* and dehulled and milled *Chohatto* when compared with each other but a non-significant (P≤0.05) difference was observed in dehulled *Desi dhan* and milled *Sukara* when compared with each other. The main reason for the decrease in the calorific value might be due to the decrease in fat and protein content after milling. Sompong et al. (2011) determined the energy (kcal) content of nine red rice cultivars and three black rice cultivars. The values were in the range of 350.7 2±0.42 to 370.53±0.95 kcal.

A significant (P≤0.05) difference was observed in NPN content was observed in all the dehulled and milled counter parts of red rice genotypes when they were compared with each other except dehulled and milled Desi dhan, which varied non significantly (P≤0.05) with each other. As is evident from the data in Table 3 milling resulted in the decrease in NPN content.

A significant (P≤0.05) difference was observed in true protein content of dehulled and milled *Jatto*, *Desi dhan*, *Sukara*, *Roda dhan* and *Chohatto* red rice genotypes when compared with each other but a non-significant (P≤ 0.05) difference was observed between dehulled and

Table 4: Effect of processing on, starch and energy NPN, true protein, free fatty acids and free amino acid content of Red rice genotypes

Parameter/ Variety	*Jatto* *T1**	*Jatto* *T2***	*Desi dhan* *T1**	*Desi dhan* *T2***	*Sukara* *T1**	*Sukara* *T2***	*Roda dhan* *T1**	*Roda dhan* *T2***	*Chohatto* *T1**	*Chohatto* *T2***	*CD (p<0.05)*
Starch percent	73.39	75.4	73.38	74.36	76.15	76.58	75.09	75.67	79.79	81.69	0.74
Energy (Kcal /100g)	360.77	359.48	360.11	357.5	370.65	360.73	357.73	350.65	362.66	358.42	0.15
NPN percent	0.43	0.39	0.14	0.13	0.99	0.91	0.09	0.04	0.23	0.21	0.02
True protein percent	5.93	5.83	7.77	7.39	9.94	9.35	9.45	9.04	7.9	7.4	0.51
Free Fatty Acid (% Oleic acid)	0.36	0.21	0.33	0.26	0.37	0.19	0.35	0.24	0.41	0.28	0.04
Free Amino Acid (% Glycine)	0.18	0.05	0.27	0.02	0.25	0.05	0.29	0.11	0.14	0.07	0.02

*T1- Dehulling, **T2- Milling

milled forms of genotypes. Similar results have been reported by Saika and Bains (1990). The decrease in the protein content of rice genotypes could be due to milling, which result in the removal of aleurone and sub-aleurone layers of the grain.

The milling of the grains decreased the free fatty acid content of red rice genotypes due to the decrease in the fat content. The results are in the agreement with those of Saika and Bains (1990) and Singh et al. (1996). The decrease in the free fatty acid content of milled red rice could be attributed to the fact that most of the fat of the rice grain was removed during the process of milling.

Milling of red rice genotypes significantly ($P \leq 0.05$) decreased the free amino acid content. The results of the present study revealed significant ($P \leq 0.05$) difference among dehulled and milled red rice genotypes except milled Jatto and milled Sukara, which differed non significantly ($P \leq 0.05$) from each other. The free amino acid values ranged from 0.14 to 0.29 percent glycine for dehulled red rice genotypes and 0.02 to 0.11 percent Glycine. Milling of the rice grain decreased the rate of free amino acid formation. Tamura et al (1963) indicated that free amino acid constituted about 0.7 percent by weight of brown rice protein and 0.2 percent of milled rice protein.

CONCLUSION

Results revealed that rice recovery after dehulling was higher as compared to the rice recovery after milling. Husk recovery and broken rice recovery was on the contrary higher in milling as compared to dehulling. The milling of red rice cultivars showed a significant ($P \leq 0.05$) decrease in grain size and proximate composition whereas density, bulk density, total carbohydrates and starch content increased. The minimum NPN content was in milled grains and maximum was in dehulled grains. Milling resulted in a decrease in true protein, free fatty acid and free amino acid content significantly ($P \leq 0.05$). Dehulling is better for retaining the nutrients in red rice cultivars.

REFERENCES

AACC 1990. *Approved Methods of American Association of Cereal Chemists*. 7th Edition. Saint Paul, Minnesotea, U.S.A., P. 240.

AOAC 1990. *Approved Methods of Association of Official Analytical Chemists*. 11th Edition. Washington, D.C., U.S.A., P. 345.

BAL S, Mukherjee RK, Nag S 1995. Parboiling characteristics of Basmati rice. *Rice India,* 5(3): 5-8.

Bouis H, Chassy BM, Ochanda JO 2003. Genetically modified food crops and their contribution to human nutrition and food quality. *Trends in Food Science and Technology,* 14(1): 191–209.

Chaudhary RC 2003. Specialty rices of the World: Effect of WTO and IPR on its production trend marketing. *Journal of Food, Agriculture and Environment,* 1(2): 34-41.

Clegg KM 1956. The application of the anthrone reagent to the estimation of starch in cereals. *Journal of the Science of Food and Agriculture,* 7(1): 40.

Deepa G, Singh V, Naidu KA 2008. Nutrient composition and physicochemical properties of Indian medicinal rice-Njavara. *Food Chemistry,* 106(1): 165-217.

Fatema K, Rahman F, Sumi N, Kobura K, Ali L 2010. Glycemic index of three common varieties of Bangladeshi rice in healthy subjects. *African Journal of Food Science,* 4(8): 531-535.

Lie S 1973. The E.B.C. Ninhydrin method for determination of free amino nitrogen. *Journal of Institutional Brewery,* 79(1): 37-41.

Lowry DH, Rosebrough NJ, Farr AL, Randa URJ 1951. Protein measurements with Folin phenol reagent. *Journal of Biological Chemistry,* 193(2): 265-275.

Meena SK, Vijayalakshmi D, Ravindra U 2009. Nutrient composition and sensory characteristics of selected varieties of aromatic rice (*Oryza sativa L.*). *Journal of Dairying, Foods & Home Science,* 28(2): 137- 141.

Mishra Vandana, Yadav Neelam, Puranik Vinita 2014. Effect of processing methods on the nutraceutical and antioxidant properties of red rice (*oryza nivara*). *International Journal of Food and Nutritional Sciences,* 13(4): 98-103.

Narain M, Siripurapu SCB, Jha H, Dwivedi VK 1978. Physico-thermal properties of rice bran. *Journal of Food Science and Technology,* 15(3): 18-19.

O'shea JO, Maguire MP 1962. Determination of calorific value of food stuff by chromic acid oxidation. *Journal of the Science of Food and Agriculture,* 13(10): 530.

Pellet LP, Young VR 1980. *Nutritional Evaluation of Protein Food.* UN University Publication, P. 257.

Saika L, Bains GS 1990. Studies on some Assam rice varieties for processing and nutritional quality. *Journal of Food Science and Technology,* 27(5): 345-348.

Sompong R, Siebenhandl-Ehn S, Linsberger-Martin G, Berghofer E 2011. Physicochemical properties of red and black rice varieties of Thailand, China and Sri Lanka. *Food Chemistry,* 124(2011): 132-140.

Sendecor W, Cochran WG 1994. *Statistical Methods*. 6th Edition. New Delhi: Oxford and IBH Publication, P. 297.

Sharma RD 1998. Basmati- a resident of India by birth. *Science Reporter*, 6(1): 10-15.

Singh S, Dhaliwal YS, Nagi HPS, Kalia M 1998. Quality characteristics of six rice varieties of Himachal Pradesh. *Journal of Food Science and Technology,* 35(1): 74-78.

Singh S 1996. *Nutritional and Quality Evaluation of Indica, Japonica and Local Genotypes of Rice and Utilization of Broken Rice*. PhD Thesis. Department of Food Science and Nutrition. Palampur, India: CSK Himachal Pradesh Krishi Vishvavidyalaya.

Tamura S, Kenmochi K 1963. Studies on the amino acid content of rice: III distribution of amino acid in rice grain. *Nipon Nogeikgaku Kasishi*, 37: 753.

Yafang S, Zhang G, Boa J 2011. Total phenolic content and antioxidant capacity of rice grains with extremely small size. *African Journal of Agriculture Research*, 6(10): 2289-2293.

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