academicJournals

Vol. 8(12), pp. 1070-1076, 4 April, 2013
DOI: 10.5897/AJAR12.1704
ISSN 1991-637X ©2013 Academic Journals
http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Effect of calcium fortification and steaming on chemical, physical and cooking properties of milled rice

Abid Ali Lone[1]*, Qazi Nissar Ahmed[1], Shaiq A. Ganai[1], Imtiyaz A Wani[2], Rayees A. Ahanger[3], Hilal A. Bhat[3] and Tauseef A. Bhat[4]

[1]Division of Post Harvest Technology, Sher-e-kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar 191121, India.
[2]Division of Pomology, Sher-e-kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar 191121, India.
[3]Division of Plant Pathology, Sher-e-kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar 191121, India.
[4]Division of Agronomy, Sher-e-kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar 191121, India.

Accepted 26 March, 2013

Milled rice of two varieties, Jehlum and Shlimar Rice-1 were subjected to seven chemical treatments and five steaming treatments for calcium fortification. Physic-chemical and organoleptic evaluations of each treatment were carried out before and after fortification. Jehlum proved superior in whiteness (L - value), starch and sugar content, volume expansion, elongation ratio and minimum cooking time, while Shalimar Rice-1 proved better in crude protein and calcium content. Fortification treatments resulted in an increase in yellowness (*b* value), water uptake, calcium content and calcium retention in cooked rice. However, significant decrease was noticed in whiteness (L- value) and redness (*a*- value) with increasing concentration of calcium in soaking solution. The highest calcium content (184.45 mg/100 g) was recorded in T_3 (Ca lactate at 0.8% a.i. Ca) followed by 184.04 mg/100 g recorded in T_6 (Ca gluconate at 0.8% a.i. Ca) samples, while the minimum (8.05 mg/100 g) was observed in T_0 (control-water dip) samples. Steaming of rice resulted in an increase in total sugar, moisture and yellowness (*b*- values), as well as calcium retention in cooked rice, while as a significant decrease was observed in colour (L and *a* values), crude protein and starch content, volume expansion, elongation ratio and water uptake.

Key words: Calcium, chemical properties, cooking quality, fortification, physic-chemical properties, steaming and milled rice.

INTRODUCTION

Rice (*Oryza sativa* L.) is the most popular cereal worldwide serving as a staple food for nearly half of the world's population and accounts for about 22% of the total energy intake (Chukwu and Osch, 2009). At least 90% of the world's rice farmers and consumers are in Asia, where rice provides up to 75% of the dietary energy and protein to 2.5 billion people (Gnanamanickam, 2009). Although milled rice is superior to brown rice in palatability and digestibility yet milling process results in loss of various nutrients in brown rice (Misaki and Yasumatsu, 1985). Depending upon the extent of milling process, two to five times of reduction have been

*Corresponding author. E-mail: aditya.lone@gmail.com, rayees83@yahoo.in.

Table 1. Recommended dietary allowance (RDA) of calcium in India and in USA (Harinarayan et al., 2007).

Group	India (mg/day)	USA (mg/day)
Adults	400	800-1000
Infants	500	500-750
Children	500	800-1300
Pregnant and lactating women	100	1200-1300

reportedly observed in nutrients such as thiamine, fat, fibre, niacin, phosphorus, potassium, iron, calcium, sodium and riboflavin at 10 to 12% degree of milling (Pillaiyar, 1988).

Furthermore, mineral malnutrition is a serious threat to the health and productivity of more than two billion people worldwide particularly to women and children (Nagpal et al., 2005). Every night 800 million people go to bed hungry and about 842 million suffer from malnutrition for one or another reason (Toenniessen, 2002). Low energy and protein intakes as well as micronutrient deficiencies are common nutritional problems for people in rice consuming countries like India, Indonesia, Myanmar, Nepal, the Philippines, Bangladesh, Sri Lanka, and Vietnam (Dexter, 1998). It can be addressed by various programmes including supplementation and fortification of commonly eaten foods with required or missing micronutrients (Venkatesh and Sankar, 2004; Aquilanti et al., 2012). Furthermore, increasing intake of a variety of calcium-containing foods might be safer than calcium supplementation because the ingestion of large quantities of calcium concentrated in tablet form may suppress bone remodelling as well as bone resorption (Niewoehner, 1988). Calcium (Ca) is an essential nutrient required for critical biological functions and an adequate intake of calcium has been demonstrated to reduce the risk for chronic diseases such as osteoporosis, hypertension and possibly colon cancer, as well as a number of other disorders associated with aging. Table 1 shows the recommended dietary allowance (RDA) of calcium in India recommended by Indian Council of Medical Research (ICMR). It is 400 mg/day for adults, 500 mg/day for infants, 500 mg/day for children and 1000 mg/day for pregnant and lactating mothers, much lower than the RDAs in the United States of America, which are 800-1000, 500-750, 800-1300 and 1200-1300 mg/day, respectively (Harinarayan et al., 2007). The mean daily intake of calcium is very low in different parts of India (Joshi and Harinarayan, 2009). In Kashmir, the mean daily intake of calcium has been reported to be 230 ± 63 mg/day for men and 178 ± 45 mg/day for women (Zargar et al., 2007). Teotia and Teotia (2008) reported that in 22 States of India, 52% of the populations have nutritional bone diseases, 40.6% have dietary calcium deficiency in critical years of growth and 8% have calcium deficiency in adults and post menopause. Thus there is an urgent need to improve calcium intake through dietary and fortified sources. Therefore, enrichment and fortification of rice are of continued interests to consumers and food processors. Among various calcium sources, calcium lactate has been frequently selected for fortification because of its non-metallic and pleasant mouth feel (Lee et al., 1995). Keeping in view the above facts, the present study on the fortification of rice with calcium was undertaken on two local varieties with the objectives of assessing the impact of calcium fortification on physic-chemical and cooking properties of milled rice.

MATERIALS AND METHODS

Two rice varieties, viz. Jehlum and Shalimar Rice-1 released by Sher-e-kashmir University of Agricultural Sciences and Technology of Kashmir (SKUAST-K) were used in the present study. Paddy was supplied by Seed Processing Centre, Division of Plant Breeding and Genetics, SKUAST-K, Shalimar. Paddy (14% MC) was cleaned and milled to rice, and samples were stored in plastic containers prior to analysis.

Method of fortification

The method employed was essentially based on the technique of fortification developed by Lee et al. (1995). The rice samples (1.5 kg of each variety) were separately soaked for three hours in calcium lactate solution or calcium gluconate solution using three concentrations (0.4, 0.6 and 0.8% a.i. Ca) for each treatment. Rice soaking solution ratio was kept constant at 1:0.75 for each treatment and soaking was done under ambient conditions (20 to 25°C). Soaking in distilled water (0% Ca) served as control. The solution/water was drained off by placing the soaked product on an 18-mesh sieve for 5 min. Each treatment sample was spread (<0.5 inch depth) onto cheese cloth in shallow stainless steel basket (9 × 11 inch in size, having 0.25 inch diameter holes at the bottom). The baskets with rice samples of each treatment were autoclaved in a retort at four different pressures and durations viz. 10 psi for 10 min (S_4), 10 psi for 5 min (S_3), 5 psi for 10 min (S_2) and 5 psi for 5 min (S_1). The samples of each fortified treatment concentrations were also maintained as un-steamed (S_0). The rice was removed from retort and all the samples including non-steamed samples were dried under ambient conditions (20 to 25°C) under shade to moisture content of 11 to 12%. Each treatment was replicated thrice in completely randomized design with 100 g of rice as a unit of replication.

Physical characteristics

Colour was determined by using colorimeter (Make: ColourTec

PCM/PSM, New Jersey). The parameters L, *a* and *b* were determined for each sample. L (Luminosity or brilliance) varies from black (0) to white (100), *a* from green (-a*) to red (+a*) and *b* from blue (-b*) to yellow (+b*).

Chemical parameters

Samples were ground to flour prior to analyses. Crude protein was determined by the method described in official methods of analysis (AOAC, 1995). Starch and total sugars were determined according to the methods described by Nagi et al. (2007). Calcium content of both cooked and un-cooked rice was determined by official methods of analysis (AOAC, 1995). About 5 g flour samples were ashed at 550 to 600°C for 8 to10 h in a muffled furnace. The residue was treated with 5 ml concentrated HNO_3 and heated on a steam bath for 5 min and filtered. The filtrate was made up to 50 ml using one N HNO_3 and aspirated into the flame generated in an atomic absorption spectrophotometer (Make: Electronic Corporation of India Limited). To avoid interference, a few drops of 1% lanthanum chloride were added to each sample.

Cooking properties

To determine the elongation ratio, 5 g rice sample was taken in a 50 ml graduated centrifuge tube and 15 ml of water was added to each tube initially and cooked for 20 min on a water bath. The cooked rice was placed on a blotter paper and the length of 10 kernels was recorded randomly before and after cooking (DRR, 2000). The elongation ratio was calculated by using Equation (1):

$$\text{Elongation ratio} = \frac{\text{Kernel length after cooking (mm)}}{\text{Kernel length before cooking (mm)}} \quad (1)$$

To calculate volume expansion, five grams of head rice were weighed into a perforated basket (height = 7 cm and internal diameter = 4.2 cm). The basket was suspended in a long-type 150 ml beaker containing 100 ml of deionized water and allowed to stand for 10 min. The beaker was transferred into a rice cooker (RC-100H, Toshiba Corp., Tokyo) with the inner pan containing 200 ml of deionized water, and then steam-cooked for 30 min. The beaker with the cooked sample was taken out and excessive water was allowed to drain for five minutes. The height of the cooked rice in the perforated basket was taken at three points with a sliding steel tape. The average of the three measurements was used in calculating cooked rice volume. Volumetric expansion was expressed as the quotient of cooked rice volume over rice sample weight (Patindol et al., 2008). Samples were cooked by using the method described by Gujral and Kumar (2003). Two grams of rice was taken in a test tube from each sample and cooked in 20 ml distilled water at 90°C in a water bath. The weight of each sample was recorded using an analytical balance and water uptake was calculated by using Equation (2):

$$\text{Water uptake (ml/g)} = \frac{\text{WC - WUC}}{\text{WUC}} \quad (2)$$

Where, WC and WUC represent the weight of cooked and uncooked rice samples respectively. The rice samples were cooked for minimum cooking time as described by Batcher et al. (1956). Two grams of rice was taken in a test tube from each sample and cooked in 20 ml distilled water at 90°C in a water bath. The minimum cooking time was determined by removing a few kernels at regular time intervals of one minute during cooking and pressing between two glass plates till no white core was left. The samples were considered to be cooked when no white core was left.

Statistical analysis

Analysis of variance (ANOVA) was carried out and critical difference (CD) test was used to describe means with 95% confidence. Analysis of variance was calculated by SPSS statistical software (SPSS Inc., Chicago, Illinois, USA) at a probability level of $p < 0.05$. Each test was performed in triplicates and the unit of replication was 100 g rice. The experimental design was completely randomized design (factorial).

RESULTS AND DISCUSSION

Physical properties

It was observed that raw milled rice of Jehlum and SR-1 exhibited L (whiteness) values of 79.62 and 77.81, *a* (redness) value of 0.28 and 0.30, and *b* (yellowness) values of 16.96 and 16.90, respectively (Table 2). The differences in colour values between the test varieties could be governed by the genetic variability of the test varieties. However, soaking of milled rice in water or fortificant solution resulted in the reduction of L and *a* values, while as *b* values increased in response to soaking. Ca fortified rice of Jehlum variety exhibited significantly higher L, *a* and *b* values compared to that of SR-1 variety. Fortification treatments differed significantly from one another with regard to all the three colour values (Table 3). It was also observed that T_0 (control) samples exhibited the highest mean L (72.80) and *a* (-0.45) values, while the lowest (67.84 and -0.90) were recorded in T_3 (Ca lactate at 0.8% a.i. Ca) samples. In case of *b* values (yellowness), mean values were recorded highest (17.45 and 17.46) in statistically at par T_6 and T_3 treatments and minimum (17.23 and 17.25) in statistically at par T_5 and T_1 as against 17.14 value recorded in T_0 samples. The results are in agreement with the findings of Lee et al. (1995) and Chitpan et al. (2005). Steaming treatments differed significantly from one another with regard to their mean L, *a* and *b* values (Table 4). There was a gradual decrease in mean L and *a* values with increasing steaming intensity from S_0 (no steaming) to S_4 (10 psi pressure for 10 min), while as an increasing trend was noticed in mean *b* values from S_0 to S_4 steaming intensity. S_0 samples provided significantly higher L (74.71) and *a* (-0.33) values compared to the rest of the steaming treatments (S_1 to S_4), which showed 65.92 to 72.84 L values and -1.26 to -0.45 *a* values. In contrast, *b* values were recorded maximum (17.84) in S_4 and minimum in S_0 (17.09) samples. Similar effects on colour have been reported by Islam et al. (2002) and Lamberts et al. (2006) in response to steaming, and by Lee et al. (1995) and Chitpan et al. (2005) in response to Ca fortificants. The discolouration and intensity of colour has been reportedly attributed to Maillard type of non-enzymatic browning reaction and processing conditions during parboiling (Lamberts et al., 2006).

Table 2. Effect of variety on physical, cooking and chemical properties of milled rice.

Variety	Physical properties			Cooking properties				Chemical properties				
	L	*A*	*b*	Volume expansion (cm^3/g)	Elongation ratio	Water uptake (g/g)	Cooking time (min)	Protein (%)	Starch (%)	Total sugars (%)	Calcium in un-cooked rice (mg/100 g)	Calcium retained on cooking (mg/100 g)
Jehlum (Raw milled)	79.62	0.28	16.96	5.10	1.72	2.42	18.33	8.42	70.26	0.74	5.36	4.70
Jehlum(Fortified)	71.59	-0.67	17.36	4.75	1.51	2.42	21.22	8.14	67.65	1.00	122.57	93.96
Shalimar Rice-1 (Raw milled)	77.81	0.30	16.90	4.96	1.67	2.44	21.33	8.65	69.76	0.71	12.46	11.70
Shalimar Rice-1 (Fortified)	69.92	-0.72	17.28	4.57	1.43	2.41	22.97	8.33	66.74	0.94	124.10	95.61
C.D. ($P \leq 0.05$)	1.26	0.01	0.02	0.01	0.01	NS	0.21	0.04	0.90	0.02	0.21	NS

*L=luminosity, varies from 100- white to black-0, b = varies from – (negative) blue to + (positive) yellow, a = varies from - (negative) green to + (positive) red.

Table 3. Effect of fortification treatments on physical, cooking and chemical properties of milled rice.

Treatment		Physical properties (Colour)			Cooking properties				Chemical properties				
Chemical	Conc. (a.i. % calcium)	L	*a*	*b*	Volume expansion (cm^3/g)	Elongation ratio	Water uptake (g/g)	Cooking time (min)	Protein (%)	Starch (%)	Total sugars (%)	Calcium in un-cooked rice (mg/100 g)	Calcium retained on cooking (mg/100 g)
Control (T_0)	0.0	72.80	-0.45	17.14	4.66	1.48	2.30	23.03	8.32	67.15	0.95	8.05	7.96
Calcium lactate (T_1)	0.4	71.64	-0.60	17.25	4.66	1.47	2.37	22.47	8.24	67.20	0.96	108.95	82.55
-do- (T_2)	0.6	70.93	-0.73	17.36	4.66	1.48	2.44	22.13	8.25	67.27	0.97	135.63	101.51
-do- (T_3)	0.8	67.84	-0.90	17.46	4.67	1.47	2.50	21.73	8.24	67.17	0.98	184.45	141.50
Calcium gluconate (T_4)	0.4	71.77	-0.55	17.23	4.66	1.47	2.36	22.13	8.23	67.15	0.96	105.54	81.12
-do- (T_5)	0.6	68.91	-0.69	17.34	4.66	1.47	2.43	21.80	8.23	67.22	0.95	136.03	98.07
-do- (T_6)	0.8	69.70	-0.85	17.45	4.65	1.48	2.51	21.40	8.24	67.18	0.98	184.04	144.79
Mean		70.51	-0.68	17.32	4.66	1.47	2.41	22.98	8.25	69.19	0.96	123.24	93.93
C.D. ($P \leq 0.05$)		2.37	0.12	0.04	NS	NS	0.01	0.40	NS	NS	NS	0.39	4.54

Chemical properties

SR-1 variety possessed significantly higher crude protein content in raw milled as well as water soaked rice as compared to Jehlum variety which could be attributed to its inherently higher protein content (Table 2). Crude protein content was observed to decrease from 8.65% in raw milled rice to 8.60% in water soaked rice of SR-1 variety and from 8.42 to 8.37% in case of Jehlum variety. Irrespective of variety, it was observed that chemical treatments (fortificant solutions) had no effect on crude protein content of Ca fortified rice Table 3). However, a significant decrease was observed in protein content with the increase in steaming intensity of fortified rice samples (Table 4). The decrease in protein content may be probably due to leaching of non-protein nitrogen, albumin and proteinaceous substances (Raghavendrarao and Julaino, 1970; Otegbayo et al., 2001). Jehlum variety possessed significantly (higher starch content in both raw milled as well as water soaked rice kernels in comparison to SR-1 variety. However, on soaking, starch content of milled rice decreased from 70.26 to 70.00% in Jehlum variety and 69.76 to 69.50% in SR-1 variety. Chemical treatments had non-significant

Table 4. Effect of steaming treatments on physical, cooking and chemical properties of milled rice.

Steaming treatment	Physical properties			Cooking properties				Chemical properties				
	L*	*a**	*b**	Volume expansion (cm^3/g)	Elongation ratio	Water uptake (g/g)	Cooking time (min)	Protein (%)	Starch (%)	Total sugars (%)	Calcium in un-cooked rice (mg/100 g)	Calcium retained on cooking (mg/100 g)
No steaming (S_0)	74.71	-0.33	17.09	4.97	1.63	2.55	18.76	8.46	69.76	0.75	123.32	74.34
5 psi for 5 min (S_1)	72.84	-0.45	17.27	4.83	1.55	2.48	20.59	8.36	68.17	0.83	123.30	86.36
5 psi for 10 min (S_2)	70.62	-0.63	17.44	4.71	1.46	2.41	21.93	8.25	67.05	0.93	123.36	98.28
10 psi for 5 min (S_3)	69.67	-0.81	17.66	4.54	1.39	2.34	23.90	8.13	65.86	1.08	123.22	104.70
10 psi for 10 min (S4)	65.92	-1.26	17.84	4.26	1.34	2.30	25.29	8.03	63.91	1.23	123.48	111.24
Mean	70.75	-0.70	17.46	4.66	1.47	2.41	22.09	8.25	66.95	0.96	123.34	94.98
C.D. ($P \leq 0.05$)	2.00	0.01	0.03	0.02	0.02	0.01	0.34	0.06	1.53	0.03	NS	3.84

effect on starch content of Ca fortified rice. The present study further indicated that steaming had a significant influence on mean starch content of Ca fortified rice, which decreased gradually with the increase in steaming intensity. Changes in starch content on steaming could be due to gelatinization of starch and some losses might have occurred during soaking and steaming process (Chukwu and Osch, 2009). Depending on the pressure, starch gets solubilized during parboiling process (Pillaiyar, 1988), which might have leached away with the soaking solution. Raghavendrarao and Juliano (1970) have attributed similar observations to appreciable decrease in molecular size of the starch in response to parboiling. Total sugar content of raw milled as well as calcium fortified rice varied significantly with respect to varieties. The mean value for total sugars in raw milled and calcium fortified rice was 0.74 and 1.00% in Jehlum and 0.71 and 0.94% in SR-1, respectively (Table 2). Chemical (fortification) treatments had non-significant impact on the level of total sugars in Ca fortified rice. Total sugars increased with soaking and the increasing intensity of steaming. Maximum mean total sugar (1.23%) was observed in S_4 (10 psi pressure for 10 min) and minimum (0.75%) was observed in S_0 (no steaming) which is shown in Table 4. Ali and Bhattacharya (1980) concluded that paddy grains are subjected to enzymatic action during the soaking stage, reducing sugars being produced from sucrose. The present findings are completely in consonance with the observations of Priestly (1976) and Lamberts et al. (2006). SR-1 proved significantly superior to Jelum variety with regard to Ca content of raw milled as well as fortified rice. SR-1 possessed significantly higher (12.46 mg/100 g) Ca content in raw milled rice as compared to Jehlum (5.36 mg/100 g) variety. On soaking in distilled water, Ca content of milled rice decreased to 11.25 and 4.65% in respective varieties, thus indicating a loss of 7.62 and 14.36% in Ca content, respectively. Irrespective of the source of Ca, fortified rice samples of both the test varieties showed a significant increase in Ca content with increasing Ca concentration in soaking solution. Irrespective of chemical and steaming treatments, Ca fortified samples of SR-1 variety exhibited significantly higher Ca content (124.10 mg/100 g) as compared to Jehlum (122.57 mg/100 g), which could be attributed to its inherently higher Ca content.

Irrespective of varieties, treatment T_3 (Ca lactate at 0.8% a.i. Ca) proved to be significantly superior by providing a maximum mean Ca content of 184.45 mg/100 g followed by 184.04 mg/100 g in T_6 (Ca gluconate at 0.8% a.i. Ca) as compared to 8.05 mg/100 g recorded in control (T_0). Soaking milled rice in the test solutions had increased the Ca content of fortified rice by 1211.05 to 2191.30% with a minimum increase recorded in samples subjected to Ca gluconate at 0.4% a.i. Ca (T_4) and a maximum increase in samples of T_3 (Ca lactate at 0.8% a.i. Ca). Varieties varied significantly in the retention of Ca in cooked raw milled rice, which was in accordance with the Ca content of raw milled rice in the respective variety. Before fortification, cooked rice of SR-1 had significantly higher Ca content (11.70 mg/100 g) than Jehlum (4.70 mg/100 g) variety. After soaking in distilled water, Ca content of cooked and 10% of Ca was lost during cooking and soaking in each variety. Almost similar findings have been reported by Cheigh et al. (1977) and Hayakawa and Igaue (1979) in response to combined washing and cooking of rice. However, test varieties showed a non-significant effect on Ca retention in fortified rice in the present study. Cooked samples showed a significant increase in retention of Ca in response to increasing Ca concentration in soaking solution as well as increasing steaming intensity. Irrespective of chemicals, treatment concentrations differed significantly from one another in Ca retention. The higher retention in T_3 and T_6 could be attributed to higher levels of Ca in these samples before cooking as a result of fortification.

Steaming had a significant effect on retention of Ca in cooked Ca fortified rice (Table 4). Maximum mean Ca content (111.24 mg/100 g) was recorded in S_4 (10 psi pressure for 10 min) while minimum (73.34 mg/100 g) was recorded in S_0 (no steaming) cooked rice samples. Ca is a stable nutrient which reportedly gets lost by leaching (Chitpan et al., 2005). In the present study, about 10% of Ca was lost in S_4 samples, while as losses to the extent of 42% were recorded in S_0 samples. More or less similar losses have been reported by Hettiarachchy et al. (1996). The retention of Ca in fortified rice might be due to physical entrapment of Ca compound in the rice grain (Lee et al., 1995). Furthermore, Ca salt may possibly form complexes with amylose of rice starch during its contact period with the grain and subsequent heat treatment (Hettiarachchy et al., 1996).

Cooking properties

Steaming treatments had a significant influence on elongation ratio, volume expansion and water uptake of Ca fortified rice, which decreased significantly with the increase in steaming intensity. The present findings are in agreement with the observations of Raghavendrarao and Juliano (1970) and Sowbhagya and Ali (1991). Maximum and minimum mean elongation ratio of 1.63 and 1.34, volume expansion of 4.97 and 4.26 cm^3/g, and water uptake of 2.55 and 2.30 ml/g were recorded in S_0 (no steaming) and S_4 (10 psi pressure for 10 min) samples, respectively (Table 4). The decrease in water uptake on parboiling is well supported by earlier findings of Mahedevappa and Desikachar (1968), Bhattacharya and Subbarao (1968), Ali and Bhattacharya (1972), Arai (1975), Anand (1983) and Patindol et al. (2008). The decrease in water uptake with increasing soaking and steaming time has been attributed to modification of starch granules by heating and parboiling process (Parnsakhorn and Noomhorm, 2008). While as Swasidisevi et al. (2010) concluded, the occurrence of partial pre-gelatinization in pre-steamed rice might have assisted in reduction of fissures within grain kernels and thus reduced water absorption. Chemical treatments exhibited non-significant impact on elongation ratio and volume expansion (Table 3). However, with the increase in Ca concentration of soaking solution, mean water uptake increased significantly from the minimum of 2.30 ml/g observed in T_0 (water dip- control) samples to maximum of 2.50 and 2.51 ml/g recorded in statistically at par T_3 and T_6 (Ca lactate or Ca gluconate at 0.8% a.i.Ca), respectively. Almost similar results have been observed by Lee et al. (1995) in Ca fortified rice and by Sudha and Leelavathi (2008) in Ca fortified wheat flour dough. Ca fortified rice developed from Jehlum variety exhibited significantly higher mean elongation ratio (1.51) as well as volume expansion (4.75 cm^3/g) compared to 1.43 ratio and 4.57 cm^3/g recorded in samples of SR-1 variety (Table 2). The differences in elongation ratio among rice varieties have also been reported by Adu-kwarteng et al. (2003), Singh et al. (2005) and Sidhu et al. (1975). However, the test varieties had a non-significant effect on water uptake of Ca fortified rice. Although chemical treatments showed varying influences on minimum time required for rice cooking yet significantly more cooking time (23.03 minutes) was required for T_0 (water dip-control) samples as against a minimum mean time of 21.40 min required for T_6 (Ca gluconate at 0.8% a.i.Ca) samples (Table 3). A minimum time required for cooking of fortified rice samples was observed to increase significantly with the increase of steaming intensity (Table 4). A minimum mean cooking time of 18.76 min required for S_0 (no steaming) samples was followed by 20.59 min for S_1 (5 psi pressure for 5 min) samples, which increased to a maximum of 25.29 min required for S_4 (10 psi pressure for 10 min). The increase in cooking time might have been due to increased kernel hardness during the steaming process (Islam et al., 2002). Ca fortified rice developed from SR-1 took significantly longer time (22.97 min) to cook as compared to 21.22 min recorded in samples of Jehlum variety (Table 2). The present findings are completely in accordance with the findings of Kaur et al. (1991), Islam et al. (2002) and Patindol et al. (2008).

Conclusion

From the present investigation, it can be concluded that, fortifying milled rice of Jehlum (V_1) or SR-1 (V_2) variety with 0.8% a.i. Ca through either Ca lactate (T_1) or Ca gluconate (T_4) resulted in enhanced levels of Ca in fortified rice as compared to raw milled rice. Steaming helped in retention of calcium in cooked rice. The fortified rice thus produced may be consumed as such and may also find applications in rice based food systems.

REFERENCES

Aquilanti L, Kahraman O, Zannini E, Osimani A, Silvestri G, Ciarrocchi F, Garofalo C, Tekin E, Clementi F (2012). Response of lactic acid bacteria to milk fortification with dietary zinc salt. Int. Dairy J. 25(1):52-59.

Adu-kwarteng E, Ellis WO, Oduro I, Manful JT (2003). Rice grain quality: a comparison of local varieties with new varieties under study in Ghana. Food Control. 14(7):507-514.

Ali SZ, Bhattacharya KR (1980). Changes in sugars and amino acids during parboiling of rice. J.Food Biochem. 4(3):169-179.

Ali SZ, Bhattacharya KR (1972). Hydration and amylose solubility behaviour of parboiled rice. Libensmittel Wissenscaft and Technology. 5: 207-12.

AOAC (1995). *Official Methods of Analysis.* Association of Official Agricultural Chemists, Washington D. C.

Anand AK (1983). Effect of pretreatments on the milling and cooking quality of some high yielding varieties of rice. M. Sc. Thesis submitted to Punjab Agricultural University, Ludhiana, India. pp. 65-67.

Arai K, Raghavendrarao SN, Desikachar HSR (1975). Studies on the effect of parboiling on japonica and indica rice. Japan Journal of Tropical Agriculture 19: 7-14.

Bhattacharya KR, Subbarao PV (1968). Effect of processing conditions on quality of parboiled rice. Central Food Technology Research Institute Reporter 476: 479-484.

Cheigh HS, Ryu JS, Jo JS, Kwon TW (1977). A type of post harvest loss: nutritional losses during washing and cooking of rice. Korean J.Food Sci.Technol. 1977(9):229-233.

Chitpan M, Chavasit V, Kongkachuichai R (2005). Development of fortified dried broken rice as a complementary food. Food. Nutr. Bull. 26(4):376-384.

Chukwu O, Osch FJ (2009). Response of nutritional contents of rice (*Oryza sativa*) to parboiling temperatures. American-Eurasian J. Sustain. Agric. 3(3):381-387.

Dexter PB (1998). Rice fortification for developing countries: opportunities for micronutrient interventions. *OMN1/USAID* 1-12.

Gnanamanickam SS (2009). Rice and its importance to human life. Progress Biological Control. 8:1-11.

Harinarayan CV, Ramalakshmi T, Prasad UV, Sudhakar D, Srinivasarao PV, Sarma KV, Kumar EG (2007). High prevalence of low dietary calcium, high phytate consumption and vitamin D deficiency in healthy south Indians. Am. J. Clin. Nutr. 85 (4):1062-1067.

Hayakawa T, Igaue I (1979). Studies on washing of milled rice: scanning electron microscopic observation and chemical study of solubilized materials. Nippon Nogali Kagaku Kaishi. 53(10):321-327.

Hettiarachchy NS, Ganasambandam R, Lee MH (1996). Calcium fortification of rice: distribution and retention. J. Food Sci. 61(1):195-197.

Islam MR, Roy P, Shimizu N, Kimura T (2002). Effect of processing conditions on physical properties of parboiled rice. Food Sci. Technol. Res. 8 (2):106-112.

Joshi SR, Harinarayan CV (2009). Vitamin D status in India – its implications and remedial measures. J. Assoc. Physic. India 57:40-48.

Lamberts L, Debie E, Derycke V, Veraverbeke WS, Deman W, Decour JA (2006). Effect of processing conditions on colour change of brown and milled parboiled rice. Cereal Chem. 83(1):80-85.

Lee MH, Hettiarachchy NS, Mcnew RW, Ganasambandam R (1995). Physiochemical properties of calcium fortified rice. Cereal Chem. 72:352-355.

Mahadevappa M, Desikachar HSR (1968). Expansion and swelling of raw and parboiled rice during cooking. J. Food Sci. and Technol. 5: 59-62.

Misaki M, Yasumatsu K (1985). Rice enrichment and fortification. In *Rice: Chemistry and Technology*. 2nd edition. American Association of Cereal Chemistry, St. Paul, Minnesota, USA. pp. 354-358.

Nagi, HPS, Sharma S, Sekhon KS (2007). *Handbook of Cereal Technology*. Kalyani Publishers, India. pp.111-155.

Nagpal S, Na S, Rathnachalam R (2005). Non-calcemic actions of vitamin D receptor ligands. Endocrinol. Rev. 26:662-667.

Niewoehner C (1988). Calcium and osteoporosis. Cereal Foods World. 33(7-8):784-787.

Otegbayo BO, Osamuel F, Fashakin JB (2001). Effect of parboiling on physico-chemical qualities of two local rice varieties in Nigeria. The J. Food Technol. Afr. 6(4):130-132.

Parnsakhorn P, Noomhorm A (2008). Changes in physico-chemical properties of parboiled brown rice during heat treatment. Agricutlural Engineering International: The CIGR E-Journal 10:1-20.

Patindol J, Newton J, Wang YJ (2008). Functional properties as affected by laboratory-scale parboiling of rough rice and brown rice. J. Food Sci. 73: 370-377.

Pillaiyar P (1988). *Rice Postproduction manual*, Wiley Eastern, New Delhi, India.

Priestly RJ (1976). Studies on parboiled rice. Part I. Comparison of characteristics of raw and parboiled rice. Food Chem. 1(1): 5-14.

Raghavendrarao SN, Juliano BO (1970). Effect of parboiling on some physicochemical properties of rice. J. Agric. Food Chem. 18(2):289-294.

Singh N, Kaur L, Sodhi NS, Sekhon KS (2005). Physico-chemical, cooking and textural properties of milled from different Indian rice cultivars. Food Chem. 89:253-259.

Sidhu SJ, Gill MS, Bains SG (1975). Milling of paddy in relation to yield and quality of rice of different Indian varieties. J. Agric. and Food Chem. 23(6) : 1183-1185.

Sudha ML, Leelavathi K (2008). Influence of micronutrients on rheological characteristics and bread-making quality of flour. Inter. J. Food sci. and Nutri. 59: 105-115.

Swasidisevi T, Sriviyakula W, Tia W, Soponronnaret S 2010. Effect of pre-steaming on production of partially parboiled rice using hot air fludization technique. Journal of Food Engineering 96: 455-462.

Teotia SPS, Teotia M (2008). Nutritional bone disease in Indian population. Indian J.Med. Res. 127:219-228.

Toenniessen GH (2002). Crop genetic improvement for enhanced human nutrition. J. Nutr. 132(9):29435-29465.

Venkatesh MG, Sankar R (2004). Micronutrient fortification of foods – rationale, application and impact. Indian J.Pediat. 71(11):997-1002.

Zargar AH, Ahmad S, Masoodi SR, Wani AI, Bashir MI, Laway BA, Shah ZA (2007). Vitamin D status in apparently healthy adults in Kashmir valley of Indian subcontinent. Postgraduate Med. J. 83 (985):713-716.