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Iron-zinc fortified extruded rice analogues in cooking quality and sensory attributes

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Abstract

Globally iron and zinc deficiencies are among the most widespread micronutrient deficiencies. Development of nutrient-dense food formulations has been proposed as a means to combat this menace. Extrusion processing is a most feasible alternative for manufacturing fortified foods. Current study optimized the extrusion processing to develop iron-zinc fortified rice via pilot-scale co-rotating twin-screw extruder. Super Basmati rice variety were fortified with NaFe EDTA+ Zn_2SO_4, 50:20 (T_1), NaFe EDTA+ ZnO, 60:20 (T_2), Elemental iron+Zn_2SO_4, 50:30 (T_3), Elemental iron+ ZnO, 60:30 (T_4) extruded and stored for three months. Cooking quality and sensory attributes of extruded rice were carried out. It was observed that extruded rice contained protein 7.01±0.49% whereas iron and zinc were 0.85±0.06 and 1.23±0.02mg/ 100g, respectively. However progression in storage led to non-significant decrease of iron and zinc contents during storage. Amylose contents varied non-significantly ranging from 23.64±1.14 to 23.98±0.25g/ 100g respectively, during three months. Likewise, alkali spreading factor (2.64±0.12 to 3.53±0.14), elongation (2.69±0.14 to 4.05±0.72g/ 100g), volume expansion ratio (0.779±0.05 to 3.70±1.32g/ 100g) and water absorption ratios (0.788±0.02 to 2.07±0.13g/ 100g) were improved significantly during storage. However, non-substantial impact over organoleptic properties was recorded. Moreover, the developed rice samples showed improved cooking quality attributes along with satisfactory consumer acceptability scores thus serve as credential for the technique appropriation.

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Introduction

Global micronutrient deficiency is estimated to about 1.6 billion people and cause economic losses ranging 2-5% of GDP (gross domestic product) in developing countries (Darnton-Hill *et al*., 2017). Micronutrient deficiencies and the negative consequences of a diet lacking in essential vitamins and minerals continue to pose significant health glitches in much of the world, especially in women and young children and female adolescents (Thurnham, 2013). However, micronutrient deficiencies have widespread and important health and economic consequences (Black *et al*., 2013) with a slight but relatively significant influence to the total global burden of diseases (Darnton-Hill, 2012; Haider and Bhutta, 2015). In Pakistan, the ubiquitous micronutrient deficiencies are of vitamin A, vitamin D, iodine, iron and zinc (NNS, 2011). The micronutrients are known to regulate many metabolic pathways and their insufficiencies cause severe physiological abnormalities that affect the health and quality of life of the individuals (Prasad, 2012). In this regard, deficiency of zinc and iron is more prevalent and has pushed the Pakistani society in quagmire of various diseases, particularly anemia. In an effort to curtail these challenges by such diet related maladies, various strategies have been devised. Amongst different approaches, fortification has been found to be one of the far reaching, vibrant and effective choices to eliminate the consequences associated with the hazard of under-nutrition. Additionally, this intervention is socially acceptable and flexible to develop the nutrients balance by combining certain deficient micronutrient in food (Prasad, 2012).

In order to provide enough food to all people, there is the holistic approach of using the food that is widely consumed. In this scenario, rice is the perfect choice as it is 2nd largely consumed cereal after wheat in Pakistan. Moreover, rice holds array of nutritious components dominated by minerals like K, Ca, Mg, Fe and antioxidants like tocopherols, tocotrienols and γ-oryzanol give credentials to rice for health enhancing perspectives for humans (Gong-Yuanssheng and Yao-Huiyuan, 2001).

Keeping in view the severity of the issue, current study was devised to enhance the nutritional status of rice by extrusion. Purposely, iron and zinc fortified extruded rice were developed. Later, extruded fortified rice was subjected to storage for three months and evaluated for cooking and eating quality parameters of fortified product. In this context, extruded fortified rice stored for three months at ambient temperature and regularly monitored (on a monthly basis) for fluctuations in amylose content, alkali spreading value, elongation, expansion and water absorption ratios. Besides, color tonality during storage and sensory evaluation was investigated during three months storage.

Materials and methods

Preparation of raw material

Rice variety Super Basmati was procured from Rice Research Institute, Kala Shah Kaku, Pakistan. The cleaning of rice grains was carried out by using mechanical aspirator for dirt, dust and foreign matter removal. The paddy of rice variety was dehulled by passing through stake sheller. The McGill laboratory mill (Rapsco, Inc, Brookshire, TX) was used to obtain two fractions of rice variety i.e. brown rice and white rice. A portion of rice fraction each of white and brown rice was milled by passing through cyclone mill (Udy Corp, Fort Collins, Co) fitted with 0.5mm sieve to get rice flour for further studies. Four fortificants i.e. elemental iron, NaFeEDTA, zinc oxide and zinc sulfate was used as source of iron and zinc.

Proximate analysis

Cleaned and graded rice grains were chemically analyzed for proximate composition. Moisture content was analyzed by using air forced draft oven (Model: DO-1–30/02, PCSIR, Lahore, Pakistan). The protein was calculated by the Method No. 990.03 (AOAC, 2006). Crude fat was estimated by AACC (AACC, 2000) Method No. 30-10. Samples were examined for crude fiber through AOAC Method No. 978.10. For determination of ash content AACC Method No. 08-01 was used. NFE was calculated according to expression: NFE (%) = 100 − (Moisture % + Crude protein % + Crude fat % + Crude fiber % + Total ash %). Mineral assay for the Basmati rice sample was performed through wet digestion following the guidelines of AACC (2000). Sodium and potassium were estimated using Flame Photometer-410 (Sherwood Scientific Ltd., Cambridge, UK) whereas, iron and zinc were determined through Atomic Absorption Spectrophotometer (Varian AA240, Victoria Australia).

Development of fortified extruder rice

The iron and zinc fortificant used in this study were elemental iron (50ppm), NaFe EDTA (60ppm), zinc oxide (20ppm) and zinc sulfate (30ppm) with four treatments i.e. T_1 (NaFeEDTA+Zn_2SO_4; 50:20, T_2 (NaFe EDTA+Zn O;60:20) T_3 (Elemental iron+Zn_2 SO_4;50:30) and T_4 (Elemental iron+Zn O; 60:30). The iron-zinc fortified rice was prepared by first adding these iron fortificant and other stabilizing ingredients to rice flour according to treatment plan. The levels of fortificants should be used by keeping in view the concentration of the desired element in the compound, RDA (%), relative bioavailability and history of use. Fortifying flour products to a level of 20-30 ppm contributes about 48% of RDA for iron (Mehansho and Mannar, 1999).

Dough prepared from this mixture was extruded using a pilot-scale, co-rotating twin-screw extruder (Model TX-52, Wenger Manufacturing, Sabetha, KS) with a 28:1 barrel length to diameter ratio was used. The extrusion system conFig.d to operate at a screw speed of 170 rpm and dry feed rate of 75kg/h. Pressure at the end of the barrel was maintained at 600 to 800 psi and product temperature was in the range of 85 to 90°C.

Target feed moisture content about 35%, which was achieved by injection of water and steam directly into the pre-conditioner and the extruder. A die con Fig.d with the rice kernel shape resembling long grain rice kernels was set up at the end of the extruder with an appropriate cutting blade system. Extruded rice kernels collected on stainless steel mesh trays. Trays were loaded into a cabinet dryer composed of a proofing cabinet with a small fan and 120-volt heating unit circulating air from the bottom of the cabinet to the top. Rice kernels were dried with the heat and fan for one to five hours and left in the cabinet overnight, approximately 12h, after which they had a water content of approximately 10g/100g.

To cook samples for vitamin and mineral analyses, a 4:7 water to rice volume/volume ratio was cooked in a 3-cup rice cooker. Cooking time (between 10 and 20min) was determined automatically by the rice cooker based on a temperature sensor. After cooking, samples were allowed to stand for approximately 5min before fluffing and serving. Cooked rice kernels were frozen in a -20ºC freezer immediately following cooking. They were then freeze-dried using a lypholizer until kernels reached an approximate water content of 5g/100g.

Storage of fortified rice

In order to evaluate the storage stability of fortificants and effect of storage on allied quality attributes, extruded grains of respective treatments were kept at room temperature for two months to monitor the impact of storage. In this context, extruder rice grains were kept in polyethylene packaging to limit ingress of moisture and relative humidity and ensure uniform quality with minimum deterioration. During storage, efforts were made to monitor variations in nutritional profile, fortificants status and other quality attributes. Additionally, an unfortified (control) was also run throughout the course of study to better relate the variations.

Iron and zinc retention in extruded rice

Iron and zinc concentration in different fortified treatments was assessed by following the standard method (AACC, 2000). The samples were loaded in Atomic Absorption Spectrophotometer to assess the concentration of iron and zinc.

Product development

For the assessment of impact of fortification and extrusion on eating and quality attributes of rice the product development phase was also carried out. Extruded fortified rice samples (different treatments) were cooked in the rice cooker, by using a 4:7 water to rice v/v ratio (1 cup of water mixed with 1.75 cups of rice). The ratio of water to rice for the extruded rice was determined in preliminary cooking trials. Extruded rice were cooked to resemble commercial rice and to achieve the least sticky texture. Cooking time was automatically set by the rice cooker (approximately 20min). The cooked product was later evaluated for sensory perception by adopting descriptive analysis method.

Cooking quality attributes

Amylose content of rice was determined at regular intervals using spectrophotometerical technique following the protocol of Butt *et al.* (2008). Alkali spreading value was calculated by using alkali spreading value according to this method at the designated intervals during storage. Elongation ratio of the cooked rice samples was measured at regular intervals by dividing the average length of cooked rice kernels with that of raw rice. The elongation ratio was estimated by the following expression

$$\text{Elongation ratio} = \frac{\text{Average ratio of 10 cooked rice grain}}{\text{Average ratio of 10 raw rice grains}}$$

The volume expansion and water absorption ratios were calculated using expressions as mentioned below

Vol. expansion ratio = (cooked rice vol – raw rice vol) /raw rice volume

Sensory evaluation

Sensory evaluation of the cooked rice samples was conducted at the Food Sensory Laboratory at the Institute of Home and Food Sciences, Government College University, Faisalabad using nine point hedonic scale system ranged from extremely liking to disliking (9 = like extremely; 1 = dislike extremely) following the guidelines of Meilgaard *et al.* (2006).

Data Analysis

Data obtained was statistically analyzed using descriptive statistics and interpreted by analysis of variance using M-Stat C software package (Michigan State University, East Lansing, MI). The Duncan's Multiple Range and Least Significant Difference test was used to determine the level of significance between the mean values of experimental samples (Steel *et al.*, 1997).

Results and discussion

Proximate and mineral analysis

The recorded values for moisture, protein, fat, fiber, ash and NFE were 9.01±0.19, 7.01±0.49, 0.85±0.04, 0.33±1.23, 0.69±0.03 and 82.11±4.25%, respectively. Moreover, sodium, potassium and calcium were detected as 3.65±0.23, 99.69±2.44 and 105.15±10.23 mg/ 100g, respectively. Likewise, iron and zinc in rice sample were detected as 0.85±0.06 and 1.23±0.02 mg/ 100g, whereas potassium, calcium and sodium content were 99.69±2.44, 105.15±10.23 and 3.65±0.23 mg/ 100g, respectively.

Verma and Srivastav (2017), explored the proximate and mineral composition of six aromatic and two nonaromatic rice varieties cultivated in India and found close proximity of proximate and mineral profile. Whereas, Zubair *et al.* (2012), also conducted proximate and mineral profiling of different Pakistani rice cultivars and concluded that nutritional profiling is dependent upon the type of cultivar, region, climatic variations as well as agronomic practices.

The variations in the proximate composition of rice due to variety and agronomic practices is well illuminated by the earlier findings of Kim *et al.* (2013) observed variations in the protein and mineral contents of Korean rice owing to change of cultivar and fertilizer. Moreover, Anjum *et al.* (2007) also investigated the proximate composition of different Pakistani rice varieties and their fractions and observed that proximate indicators varied significantly among all milled fractions and cultivars. Likewise, trend was observed regarding mineral contents.

Iron and zinc retention in fortified treatments

Highest levels of iron were detected in T_4 followed by T_3, T_2 and T_1 as 4.609±0.36, 3.004±0.15, 3.001±0.14 and 2.334±0.12mg/ 100g, respectively depicted in Table 1. However, treatment T_0 showed minimum value as 0.793±0.03mg/ 100g. During the storage, a gradual decline in iron contents was observed.

At the 0 day, it was recorded as 3.015±0.23mg/ 100g however, with the passage of time it was reduced to 2.969±0.14 and 2.939±0.13 and 2.918±0.09mg/ 100g at 30th, 60th and 90th day, respectively. Likewise, in treatments a decline in Fe level was observed from 3.059±0.04, 4.674±0.25, 2.394±0.12, 4.113±0.25mg/ 100gm at 0 day to 2.964±0.01, 4.560±0.02, 2.281±0.14 and 4.018±0.45mg/ 100g at 90th day for T_1, T_2, T_3 and T_4, respectively (Table 1).

Table 1. Means for Iron and Zinc content in extruded iron zinc fortified rice.

	Treatments	Day-0	Day-30	Day-60	Day-90
Iron (g/100g)	T_0	0.836±0.02	0.788±0.02	0.779±0.05	0.769±0.14
	T_1	4.113±0.25	4.075±0.35	4.037±0.36	4.018±0.45
	T_2	3.059±0.04	3.011±0.25	2.983±0.45	2.964±0.01
	T_3	4.674±0.25	4.617±0.36	4.588±0.44	4.560±0.02
	T_4	2.394±0.12	2.356±0.09	2.308±0.12	2.281±0.14
	Mean	$3.0153±0.23^a$	$0.788±0.02^c$	$0.779±0.05^c$	$2.9184±0.09^b$
Zinc (g/100g)	T_0	1.12±0.04	1.10±0.09	1.08±0.02	1.05±0.23
	T_1	2.22±0.06	2.18±0.16	2.13±0.12	2.09±0.12
	T_2	2.65±0.12	2.60±0.45	2.55±0.03	2.49±0.06
	T_3	3.43±0.21	3.36±0.10	3.29±0.04	3.23±0.09
	T_4	4.05±0.31	3.97±0.09	3.89±0.05	3.81±0.05
	Mean	2.69±0.14	2.64±0.12	2.58±0.13	2.53±0.08

T_0: Unfortified diet (control)

T_1: Fortified rice (NaFeEDTA+Zn_2SO_4 (50 ppm NaFeEDTA + 20 ppm Zn_2SO_4)

T_2: Fortified rice (NaFeEDTA+ ZnO (60 ppm NaFeEDTA + 20 ppm ZnO)

T_3: Fortified rice (Elemental iron+ Zn_2 SO_4 (50 ppm NaFeEDTA + 30 ppm Zn_2SO_4)

T_4: Fortified rice (Elemental iron+ ZnO (60 ppm NaFeEDTA + 30 ppm Zn_2SO_4)

Likewise trend was observed for zinc contents, maximum in T_4 as 3.93±0.09, followed by T_3 3.33±0.16, T_2 2.57±0.12 and T_1 2.15±0.07 whilst minimum level 1.09±0.04 was detected in control (T_0). With passage of storage, a steady decline was observed at the initiation to termination of study that varied from 2.69±0.14 to 2.53±0.08mg/ 100g, respectively. Pinkaew *et al.* (2012) conducted a study to evaluate the impact of different techniques for rice fortification with minerals like iron, zinc and vitamin A to overcome the complications associated with micronutrients in school going children of Thailand and inferred that for the retention of fortificant hot extrusion is a viable technique. Earlier, Li *et al.* (2008) concluded from the study that among the different iron fortificants, elemental iron and NaFeEDTA based treatments showed minimum iron losses with less oxidation. Likewise, Moretti *et al.* (2005) observed that extruded rice grains showed good fortificant retention, storage stability and color tonality. Later, Kuong *et al.* (2016) concluded in a study during storage zinc and iron exhibited more stability as compared to vitamin A. However, magnitude of retention was dependent upon the fortification technique. Furthermore, they recorded more losses in all the micronutrients in coated samples as compared to extruded rice. The observed losses regarding zinc and iron were ranged from 5 to 10% as compared to vitamin A i.e. 20 to 40% in extruded samples. They were of the view that the storage at varying temperature caused significant diminishing effect on Vitamin A. However, zinc and iron losses were found non-significant. The rice fortification to overcome zinc and iron deficiencies should be adapted owing to its effectiveness and economics.

Cooking quality attributes

Eating and cooking quality of rice is often varied with the amount of amylose contents thus it used as a tool to access the eating and cooking attributes of rice. Means (Table 2) relating to amylose content of iron-zinc fortified rice expounded non-significant variations in amylose contents due to treatments and recorded contents highest in T_0 (26.15±1.25) followed by T_1 (25.14±1.25), T_2 (22.84±1.04), T_3 (23.06±1.12) and T_4 (23.83±1.36g/ 100g), with non-significant variation. Regarding storage interval, a significant gradual reduction in amylose contents was noticed varied from 24.64±1.14g/ 100g at initiation to 24.14±0.02, 24.06±0.10 and 23.08±0.25g/ 100g at the 0, 30, 60 and 90th day, respectively.

The decrease in amylose content might be due to the fractional changes in its molecular weight which decreased during storage. The eating quality of rice is often determined through alkali spreading value which is the estimation of starch gelatinization temperature.

Means (Table 2) depicted regarding alkali spreading factor revealed highest value in T_4 (4.22±0.41) followed by T_3 (4.21±0.32), T_2 (4.17±0.21) and T_1 (4.13±0.34) whilst, minimum was detected in T_0 as 4.12±0.36. In contrary, significant gradual decline was observed during storage. The alkali spreading value was declined as 4.26±0.45 at 0 day to 4.20±0.25 and 4.13±0.47 at 30th and 60th day, respectively. Moreover, at the end of the trial (90th day), observed alkali spreading value was 4.05±0.72.

Table 2. Means for cooking quality attributes in extruded iron zinc fortified rice.

	Treatments	Day-0	Day-30	Day-60	Day-90
Amylose content (g/100g)	T_0	0.836±0.02	26.07±1.01	26.59±1.1	27.12±1.45
	T_1	4.113±0.25	23.69±1.24	24.17±1.5	24.65±1.02
	T_2	3.059±0.04	23.24±1.01	22.78±1.3	22.32±0.86
	T_3	4.674±0.25	23.52±1.25	23.05±1.04	22.59±1.98
	T_4	2.394±0.12	24.22±1.04	23.74±0.96	23.26±2.54
	Mean	3.0153±0.23^{b}	24.14±1.02^{a}	24.06±1.10^{a}	23.98±0.25^{ab}
Alkali spreading factor	T_0	1.10±0.09	3.01±0.8	3.26±0.24	3.44±0.03
	T_1	2.18±0.16	3.07±0.12	3.32±0.21	3.50±0.02
	T_2	2.60±0.45	3.10±0.13	3.35±0.14	3.54±0.06
	T_3	3.36±0.10	3.14±0.4	3.39±0.14	3.57±0.08
	T_4	3.97±0.09	3.15±0.9	3.41±0.21	3.60±0.07
	Mean	2.64±0.12^{c}	3.09±0.6^{b}	3.35±0.34^{ab}	3.53±0.14^{a}
Elongation ratio	T_0	1.12±0.04	4.15±0.39	4.07±0.91	3.99±0.37
	T_1	2.22±0.06	4.19±0.12	4.11±0.96	4.02±0.38
	T_2	2.65±0.12	4.21±0.51	4.13±0.14	4.05±0.21
	T_3	3.43±0.21	4.28±0.47	4.19±0.38	4.11±0.31
	T_4	4.05±0.31	4.22±0.49	4.18±0.87	4.13±0.23
	Mean	2.69±0.14^{d}	4.20±0.25^{ab}	4.13±0.47^{b}	4.05±0.72^{c}
Water absorption ratio	T_0	0.788±0.02	2.02±0.01	2.06±0.14	2.10±0.36
	T_1	4.075±0.35	2.03±0.05	2.05±0.03	2.07±0.05
	T_2	3.011±0.25	2.11±0.02	2.17±0.05	2.24±0.06
	T_3	4.617±0.36	2.06±0.14	2.02±0.06	1.98±0.09
	T_4	2.356±0.09	2.05±0.12	2.01±0.07	1.97±0.14
	Mean	0.788±0.02^{b}	2.05±0.16^{a}	2.06±0.12^{a}	2.07±0.13^{a}
Volume expansion ratio	T_0	0.779±0.05	3.36±1.54	3.43±1.36	3.65±1.45
	T_1	4.037±0.36	3.40±1.23	3.47±1.45	3.69±1.23
	T_2	2.983±0.45	3.42±1.25	3.49±1.20	3.71±1.24
	T_3	4.588±0.44	3.43±1.45	3.50±1.06	3.71±1.02
	T_4	2.308±0.12	3.48±1.63	3.54±1.12	3.76±1.96
	Mean	0.779±0.05^{b}	3.42±1.14^{ab}	3.48±1.39^{ab}	3.70±1.32^{a}

T_0: Unfortified diet (control)

T_1: Fortified rice (NaFeEDTA+Zn_2SO_4 (50 ppm NaFeEDTA + 20 ppm Zn_2SO_4)

T_2: Fortified rice (NaFeEDTA+ ZnO (60 ppm NaFeEDTA + 20 ppm ZnO)

T_3: Fortified rice (Elemental iron+ Zn_2 SO_4 (50 ppm NaFeEDTA + 30 ppm Zn_2SO_4)

T_4: Fortified rice (Elemental iron+ ZnO (60 ppm NaFeEDTA + 30 ppm Zn_2SO_4)

It is evident from (Table 2) the elongation ratio of iron-zinc fortified rice that the elongation ratio varied non-significantly among the treatments from 2.02±0.10 to 2.14±0.03 in T_4 and T_2 , respectively. The recorded values for this trait in T_0, T_1 and T_3 were 2.04±0.04, 2.11±0.05 and 2.04±0.04, respectively. During storage elongation ratio improved but most pronounced effect was observed for fortified rice. The recorded value of this trait at 0 day was 2.03±0.26 which improved to 2.05±0.16, 2.06±0.12 and 2.07±0.13 at 30, 60 and 90th days, respectively. It is inferred from results that the treatment of rice caused improved elongation ratio as compared to control thus testify the suitability of current techniques and helpful in the validation of data. Water absorption ratio varied non-significant due to treatments in whole study. The lowest value of this trait was noticed in T_0 (3.13±0.04) whilst maximum in T_4 (3.28±0.03) (Table 2). In contrary, storage intervals imparted significant improvements in this trait. The recorded value at the initiation of study was 2.88±0.09 that uplifted to 3.53±0.14 at the termination of storage. Moreover, the recorded values for 30th and 60th day were 3.09±0.6 and 3.35±0.34, respectively.

The maximum value for volume expansion ratio was observed in T_4 as 3.44±1.12 followed by T_3 and T_2 3.56±1.26, 3.50±1.25 and 3.48±1.25, respectively. Moreover, the minimum volume expansion ratio was recorded in T_1 and T_0 as 3.48±1.25 and 3.44±1.21, respectively. During storage interval, progressive increase was observed in the volume expansion ratio. The variation was 3.39±1.09 at initiation to 3.42±1.14 and 3.70±1.32 at 30th and 90th day, respectively.

The findings regarding the cooking qualities and related attributes in current study is further validated by the observations of Sodhi *et al.* (2003) they conducted a trial to evaluate the impact of rice storage on its physicochemical, textural and cooking attributes on Basmati-370 and Sharbati rice. They observed significant increase in cooking time, elongation ratio, free fatty acid with decrease in amylose contents. They ascribed reduction in amylose content to the typical characteristic especially hardness, packing, cohesiveness and chewiness, variety with higher in these traits exhibited more amylose decline. They deduced that might be the formation of amylose lipid compels caused water absorption thus resulted less chances to disintegration.

During storage, numerous physicochemical changes have been occurred in rice which is dependent upon multiple factors like storage conditions especially temperature and storage humidity that ultimately affected cooking and sensory attributes of rice. In this context, storage temperature played an instrumental role to determine the cooking properties and peak viscosity (Daniels *et al.*, 1998). The impact of variety on cooking attributes during storage is further expounded by the earlier work of Lee *et al.* (1989) they investigated the impact of varieties on cooking attributes during storage. The findings delineated that the cooking quality and water uptake ratio was significantly affected by variety. Likewise, observations were recorded for amylose contents, hardness and protein contents. They correlate this attribute to protein-starch interaction resulting in an increased volume expansion with the progression in storage time and increase in temperature that ultimately enhanced water absorption ratio.

There is a relation between sensorial, textural and cooking attributes of rice at varying storage conditions that caused enhancement in moisture, water absorption ratio and elongation volume whereas, a significant decline was observed in amylose and alkali spreading ratio (Butt *et al.*, 2008).

Sensorial attributes

Regarding aroma of iron-zinc fortified rice showed maximum scores in T_0 unfortified diet as 7.65±0.02 trailed by T_1, T_2, T_3 and T_4 as, 7.63±0.01, 7.63±0.04, 7.63±0.03 and 7.62±0.03, respectively (Fig. 1A). Storage caused significant effect on this trait and with passage of storage a non-significant decline was observed in this trait. The recorded variations in different treatments from initiation to termination T_1, T_2, T_3 and T_4 varied from 7.65 to 7.61, 7.66 to 7.61, 7.64 to 7.60 and 7.64 (0day) to 7.59 at 30th to 90th day, respectively. Means regarding hardness indicated that this parameter varied from 8.87±0.04 to 8.78±0.03 in different treatments. In this context, maximum hardness was observed in T_0 (8.87±0.04) whilst minimum in T_3 as 8.78±0.03. The variations regarding storage was recorded as 8.85±0.02 to 8.78±0.04 at initiation to termination, respectively (Fig. 1B). Likewise, for sweetness treatments did not caused any significant difference among the consumer preferences. The recorded sweetness scores were 6.52±0.02, 6.57±0.04, 6.55±0.01, 6.59±0.04 and 6.61±0.05, in T_0, T_1, T_2, T_3 and T_4, respectively. Regarding storage the recorded variations in sweetness score were 6.60±0.04 at 0 day to 6.58±0.03, 6.56±0.06 and 6.54±0.04 at 30, 60 and 90th day, respectively (Fig. 1C).

Hedonic rating regarding the looseness in iron-zinc fortified rice showed that the treatments caused non-significant differences in consumer response highest scores were given to T_3 as 7.56±0.01 followed by 7.54±0.04 in T_4. As far as storage is concerned, a non-momentous decline in sensory scores was observed ranging from 7.53±0.03 to 7.49±0.05 at 0 to 90 days (Fig. 1D). As far as whiteness is concerned, similar non-significant variation was noticed . Accordingly, T_1 had maximum score 7.57±0.02 trailed by T_0 unfortified diet, T_2 and T_4 by 7.54±0.03, 7.51±0.07 and 7.49±0.03, respectively. However, T_3 got lowest scores from panelists 7.47±0.05 (Fig. 1E). A non-significant decline was observed with regard to storage from 7.53±0.05, 7.52±0.03, 7.51±0.06 and 7.50±0.06 at 0, 30, 60 to 90 days, respectively.

It is depicted from (Fig. 1F) that the glossiness scores of iron-zinc fortified rice varied non-significantly among the treatments and maximum score was attained by T_0 and T_4 as 7.65±0.06 and 7.65±0.03, respectively. Whilst minimum ranking was assigned to T_2 and T_3, as 7.62±0.02 and 7.62±0.04, respectively. Storage also caused non-substantial decline from 7.66±0.04 to 7.61±0.06 at 0 to 90th day, respectively. The trend observed during instant research regarding the sensorial attributes of fortified rice samples is in line with the early findings of Porasuphatana *et al.* (2008) conducted atrial for the development of rice flour based noodles fortified with multiple nutrients. Besides, many other analyses they also carried out hedonic response testing to evaluate the consumer acceptability regarding the rice based noodles. They observed non-significant differences among the control and experimental sample regarding the different sensorial attributes. They concluded that the rice fortification was acceptable as indicated by consumer acceptability score calculated by triangle test. Moreover, Le *et al.* (2007) also observed the non-significant difference among the consumer preferences about fortified and unfortified rice samples by using preference test.

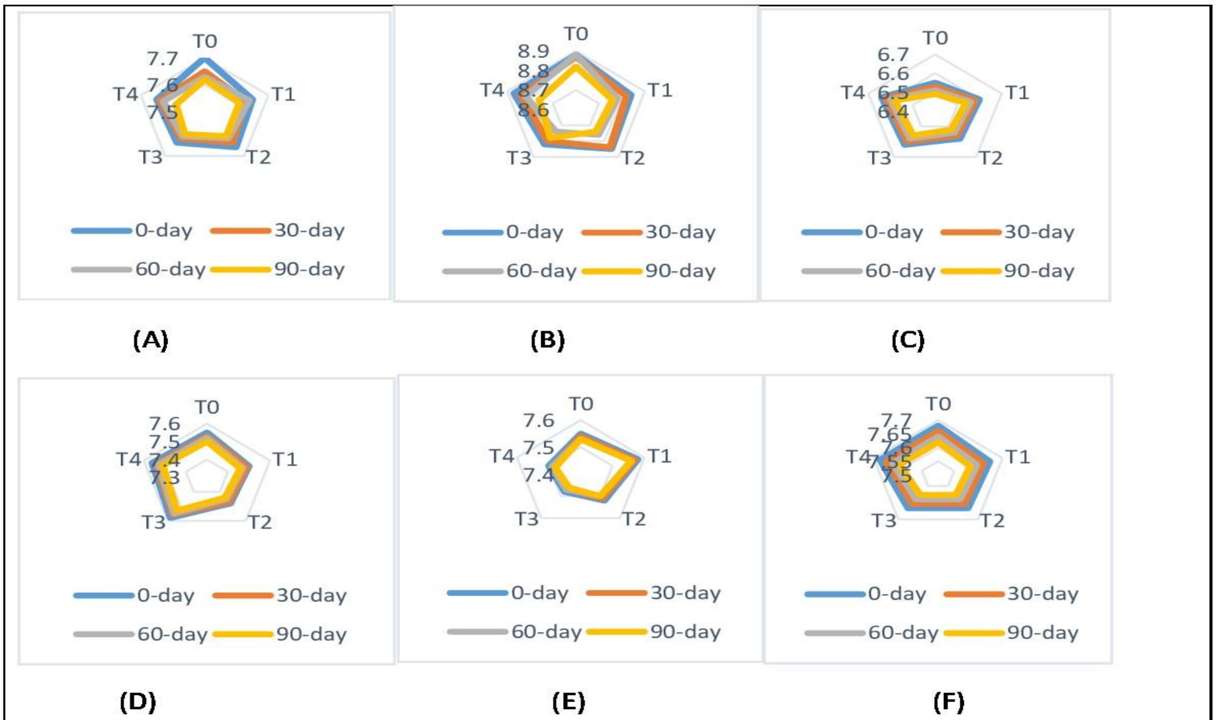

Figure 1. Effect of iron-zinc fortified diet on sensory parameters during storage period (A); Aroma (B); Hardness (C); Sweetness (D); Looseness (E); Whiteness (F); Glossiness of extruded iron zinc fortified rice.

T_0: Unfortified diet (control),
T_1: Fortified rice (NaFeEDTA+Zn_2SO_4 (50 ppm NaFeEDTA + 20 ppm Zn_2SO_4),
T_2: Fortified rice (NaFeEDTA+ ZnO (60 ppm NaFeEDTA + 20 ppm ZnO),
T_3: Fortified rice (Elemental iron+ Zn_2 SO_4 (50 ppm NaFeEDTA + 30 ppm Zn_2SO_4)
T_4:Fortified rice (Elemental iron+ ZnO (60 ppm NaFeEDTA + 30 ppm Zn_2SO_4)

Conclusion

Results from study revealed that the iron and zinc fortification of rice through extrusion is effectual regarding the fortificant stability, sensory and cooking quality attributes. More pronounced effect was observed for T_4 (Elemental iron+ ZnO, 60:30) may be ascribed its higher iron contents and solubility as compared to its other counterpart. Moreover, the developed rice samples showed improved cooking and eating attributes alongside satisfactory consumer acceptability scores thus serve as credential for the technique appropriation. Extrusion processing on large-scale would be more effective in reaching the growing poor urban areas. Conclusively, further research on efficacy trials and iron bioavailability from fortified extruded rice are required.

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