

COOKING AND EATING QUALITY ATTRIBUTES OF EDIBLE COATED ZINC FORTIFIED RICE

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The current research was designed to assess the impact of storage on zinc retention and cooking & eating quality traits of zinc fortified super basmati rice. Purposely, sodium alginate and starch based edible coatings were introduced to retain zinc sulfate and zinc oxide, each @ 25 & 45 ppm within their matrix. Afterwards, the resultant coating formulations were applied uniformly on rice kernels, packed in polythene bags and stored under ambient conditions for further analyses. Amongst treatments, Zn concentration was ranging from 1.43 ± 0.05 to 5.85 ± 0.21 mg/100g. During storage, a slight decrement was recorded in zinc retention from 4.33 ± 0.15 mg/100g at initiation to 4.28 ± 0.16 mg/100g at 90th day (termination). Furthermore, statistical inferences showed significant influence of storage on cooking & eating characteristics with special reference to alkali spreading factor and elongation, water absorption & volume expansion ratios. During storage, a declining trend was observed in amylose content from 23.57 ± 1.07 to 22.16 ± 0.99 g/100g and alkali spreading factor from 4.24 ± 0.16 to 3.38 ± 0.19 , whereas elongation, water absorption & volume expansion ratios indicated increments from 1.91 ± 0.05 to 2.39 ± 0.07 , 2.87 ± 0.08 to 3.40 ± 0.17 and 3.59 ± 0.15 to 3.87 ± 0.17 , respectively. Resultantly, it is found that aged rice possess better eating and cooking characteristics as compared to fresh counterparts, whereas impact of fortificants was non-significant. In the nutshell, Zn fortified edible coated rice has proven as a novel approach to improve the zinc status of the communities.

Keywords: Zinc fortification, edible coating, storage, super basmati rice, eating and cooking quality

INTRODUCTION

Rice (*Oryza sativa* L.) is a dietary staple for half of the world and largely popular amongst 39 countries (Hussain *et al.*, 2014). It supplies around 20-23% energy all over the globe with rice kernel contributing 70-80% of energy in the form of carbohydrate and protein 6-7% in addition to minerals, mainly Ca, Mg and P along with minor quantities of Fe, Zn, Cu and Mn in outer endosperm & bran and fat predominantly in bran portion (Shabbir *et al.*, 2008; Li and Jiang, 2015). Rice holds unique position in Pakistan's economy after wheat and occupies 2.7 million/hectares with annual production of 6.8 million tons as reported in Economic survey of Pakistan (GOP, 2015). Amongst rice varieties, Super Basmati was developed in Pakistan and contains unique aromatic properties (Napasintuwong, 2012). It contains intermediate characteristics between *Indica* and *Japonica* with intermediate amylose content 20 to 25% (Imran *et al.*, 2014). One of the important challenges being faced by the Pakistani population is micronutrient malnutrition. In this context, the involvement of poor socioeconomic status, nutritional transition and societal reliance on nutrient deficient monotonous staples further aggravate the severity of this nutritional catastrophe (FAO, 2010; Gayer and Smith, 2015). The major culprits of zinc insufficiency are infants, children, pregnant and lactating women (Pickett and Wilkinson, 2015).

Globally, hypozincemia has emerged as a serious health threat, affecting almost half of the population (FAO, 2007; Haider and Bhutta, 2009). Likewise, Pakistan is also facing zinc malnutrition which results in the stunted growth, poor body development, compromised cognitive performances of individuals. Domestically, nearly 41.3 & 47.6% non-pregnant & pregnant women are reported as zinc deficient (NNS, 2011). Thus, nutritional interventional approaches such as food fortification coupled with nutritional education seem viable solution to address micronutrient inadequacy (Wimalawansa, 2013).

The human body contains nearly 2-4 g of zinc out of which 0.1% replenishes daily (Maret and Sandstead, 2006; Jansen *et al.*, 2012). On the basis of gender, the RDA of Zn is 12 and 15 mg/day for females and males, respectively (El Behairy *et al.*, 2011). Being dietary staple, rice could better serve as a mass fortification vehicle to tackle the menace of zinc malnutrition. This strategy could restore diminished nutritional quality of milled white rice e.g. low in zinc content; unpolished rice 25.5-37 mg/kg and polished rice 16-26.5 mg/kg. Additionally, it could cope with poor bioavailability attributed to the presence of phytic acid in higher amounts (Cakmak, 2008; Sellappan *et al.*, 2009). In this regard, ZnSO₄, ZnO, ZnCl₂, Zn gluconate and Zn acetate have gained the GRAS status due to better solubility and bioavailability (Khalid *et al.*, 2014). For effective retainability

during storage, edible coating is considered to enwrap active molecules such as vitamins, minerals, extracts and flavoring compounds. Alongside, fortification by surface coating eliminates the costs of packaging (Steiger *et al.*, 2014).

Considering the severity of zinc deficiency, the current research was planned to improve the nutritional status of milled rice grains using zinc fortified edible coatings. Purposely, sodium alginate and starch based zinc fortified coatings containing desirable amounts of Zn salts in the form of zinc sulfate and zinc oxide were formulated and applied on rice. Later, the rice samples were stored at ambient temperature for duration of three months. During storage intervals (Day 1st, 30th, 60th and 90th), fluctuations in zinc content and cooking & eating physicochemical characteristics involving quantification of amylose, alkali spreading value and elongation-, volume expansion- & water absorption ratios) of zinc fortified rice were tested to relate the impact of fortification of rice with storage.

MATERIALS AND METHODS

The rice (Super Basmati) was procured from local market and subjected to mechanical aspirator to remove any foreign matters. The uniformly graded rice kernels were fortified with zinc salts (ZnSO₄ and ZnO) using sodium alginate and starch based edible coatings, each at 25 & 45 ppm concentrations (Table 1). The sodium alginate based edible coating was prepared following the protocol of Rojas-Grau *et al.* (2008), whereas starch based edible coating solution was formulated as described by Pagella *et al.* (2002). Developed coatings were uniformly applied on rice samples via soaking procedure followed by drying using cabinet air drier (Harvest saver Model # R-5A, Commercial dehydrator system, Inc.). Afterwards, the dried rice samples were packed using polythene bags to avoid transference of moisture and relative humidity. During storage (03 months) under ambient conditions, fluctuations in zinc retention and cooking & eating quality attributes; amylose content, alkali spreading factor, elongation ratio, water absorption ratio & volume expansion were monitored. Uncoated counterpart (control) was run for comparative purpose.

Table 1. Study plan for the development of fortified edible coatings.

Coating types	Fortificants	Treatments	Fortificant levels (ppm)
Control	---	T ₀	---
Sodium Alginate	ZnSO ₄	T ₁	25
		T ₂	45
	ZnO	T ₃	25
		T ₄	45
Starch	ZnSO ₄	T ₅	25
		T ₆	45
	ZnO	T ₇	25
		T ₈	45

Zinc stability: The zinc contents in various zinc fortified coated rice were measured considering the standard procedure of AACC (2000). Accordingly, coated rice sample (10 g) was subjected to ashing in muffle furnace at 500°C followed by wet digestion using few drops of HNO₃ or HCl and re-ashing. The resultant sample cake was broken using 10 mL HCl and boiled till dry. Subsequently, the residues were re-dissolved in 20 mL of 2 N HCl. Later, digested sample was filtered followed by water dilution to 100 mL volume. The sample absorbance was determined via Atomic Absorption Spectrophotometer (Varian AA240, Victoria Australia) equipped with air-C₂H₂ burner and zinc lamp at 213.9 nm.

Cooking and eating quality attributes:

Amylose content (AC): The concentration of amylose in rice samples was determined as outlined by Butt *et al.* (2008). The fortified rice flour (100 mg) was treated with 1 mL of 95% ethanol and 9 mL of 1 N NaOH followed by 10 min boiling to gelatinize starch. After cooling, total volume was brought to 100 mL using distilled water. Later, 5 mL of starch solution (aliquot) was transferred to a volumetric flask with 100 mL capacity followed by the addition of 1 mL 1 N CH₃COOH and 2 mL iodine solution. Lastly, distilled water was added to make the final volume up to 100 mL trailed by 20 min resting time. The optical density of sample was taken at 620 nm (λ_{max} for amylose) via UV-Vis Spectrophotometer (CECIL CE 7200) and compared with standard curve of potato amylose. To reach the final value, the attained value was multiplied with dilution factor (Df) as stated in the expression below;

$$\text{Amylose level} = \text{Absorbance value} \times \text{Slope of standard curve} \times \text{Df}$$

Alkali spreading value: The alkali spreading values is a measure of gelatinization temperature of rice kernels *i.e.* recorded as described by Butt *et al.* (2008). For analysis, the rice grains (n=6) were spaced uniformly in a petri dish and immersed in 10 mL 1.7% KOH solution. Afterwards, this petri dish was placed in an incubator at 30°C for 24 hr followed by visual examination to assess the level of intactness, rated on 7-point spreading scale (1; intact kernel to 7; greatly dispersed & intermingled kernel). The values of six kernels were averaged to produce one value per sample. On the basis of average spreading scale values; 1-3, 4-5 and 6-7, gelatinization temperature of rice grains were categorized as high (75-79 °C), intermediate (70-74 °C) and low (55-69 °C), respectively.

Elongation ratio: The elongation ratio of rice samples were measured by dividing the mean length of rice kernels (n=10) on cooking to that of raw rice following the protocol of Hegde *et al.* (2013). The elongation ratio was determined by using the following expression;

Elongation ratio of rice =

$$\frac{\text{Mean value of length of 10 rice grains after cooking}}{\text{Mean value of length of 10 raw rice grains}}$$

Water absorption/uptake ratio: The water uptake ratio of rice samples was analyzed as outlined by Shrestha *et al.* (2003).

The water uptake value was calculated according to the following equation;

$$\text{Water uptake ratio of rice} = \frac{\text{Cooked rice weight}}{\text{Raw rice weight}}$$

Expansion ratio: The volume expansion ratio of rice was assessed by adopting the method of Butt *et al.* (2008), following the mathematical expression as given herein;

$$\text{Volume expansion ratio} = \frac{\text{Cooked rice volume}}{\text{Raw rice volume}}$$

Statistical analysis: The obtained data for each parameter was analyzed through statistical software Statistix 8.1 using two-factor factorial under completely randomized design considering treatment formulation and storage as the two factors under study. Furthermore, ANOVA was performed to measure the level of significance (*p* value) followed by LSD multiple comparison tests to assess the differences among the means (Mason *et al.*, 2003).

RESULTS

Zinc contents in fortified treatments: The maximum mean values for zinc concentration among fortified rice samples were achieved in treatments carrying higher salt concentrations; T₄ (5.85±0.21 mg/100g), T₂ (5.82±0.22 mg/100g), T₈ (5.68±0.27 mg/100g) and T₆ (5.46±0.24 mg/100g). On the other hand, treatments containing 25 ppm concentration of salts showed lower zinc content; T₃ (3.91±0.18 mg/100g), T₁ (3.69±0.16 mg/100g), T₇ (3.52±0.15 mg/100g) and T₅ (3.39±0.13 mg/100g). Nevertheless, control sample showed minimum zinc content *i.e.* 1.43±0.05 mg/100g, accordingly. During storage, non-significant decline was noted in zinc level from 4.33±0.15 mg/100g at initiation to 4.31±0.18 and 4.30±0.13 mg/100g at Day 30 and 60, correspondingly. Moreover at 90th day, zinc level was reduced to 4.28±0.16 mg/100g. Amongst treatments, a slight change in Zn retention (mg/100g) was noted, reduced from 3.72±0.15 to 3.66±0.16 (T₁), 5.85±0.20 to 5.79±0.17 (T₂), 3.94±0.16 to 3.90±0.15 (T₃) and 5.87±0.21 to 5.84±0.25 (T₄) at initiation to Day 90. Likewise, the rest of the treatments including T₅, T₆, T₇ and T₈ showed variation in Zn content from 3.42±0.14, 5.49±0.19, 3.56±0.13 and 5.71±0.27 at initiation to 3.35±0.10, 5.43±0.18, 3.50±0.11 and 5.66±0.19 mg/100g at termination, respectively. However, the zinc content in unfortified counterparts (T₀) varied from 1.49±0.04 to 1.41±0.06 mg/100g at mentioned intervals, accordingly (Fig. 1).

Cooking and eating quality attributes

Amylose content: The amylose concentration of rice determines cooking & eating perspectives of rice ultimately influences acceptability and palatability criteria of consumers. The mean squares regarding amylose level of fortified rice presented non-momentous difference amongst treatments, storage intervals and interaction between treatments & storage as shown in (Table 2). Highest amylose content of

fortified rice samples was revealed in T₈ (23.70±0.88 g/100g) followed by T₇, T₅ and T₆ with 23.31±0.97, 23.19±0.86 and 23.16±1.02 g/100g, respectively. A slight decrement was observed over 3-month storage, differed from 23.57±1.07 at initiation to 23.32±1.12, 22.69±1.01 and 22.16±0.99 g/100g at Day 30, 60 and 90, accordingly.

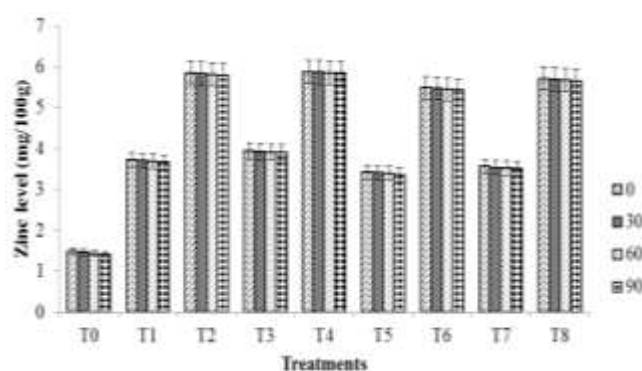


Figure 1. Variations in zinc content (mg/100g) for various treatments during storage intervals; 0, 30, 60 & 90 days.

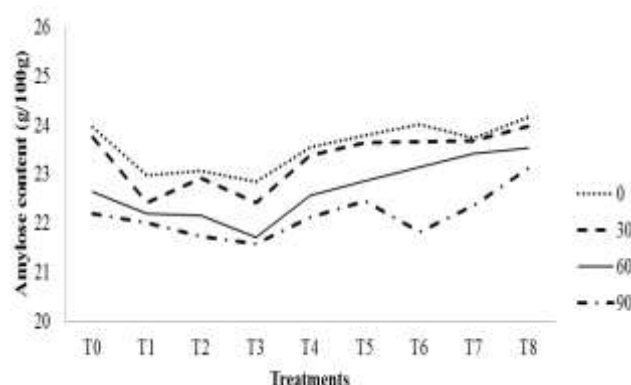


Figure 2. Variations in amylose content (g/100g) for various treatments during storage intervals; 0, 30, 60 & 90 days.

Alkali spreading factor: Alkali spreading value determines eating quality being an indicator to assess the gelatinization temperature. Alkali spreading factor varied momentarily regarding storage, whereas treatments and interaction effect showed non-significant variations. Mean values for alkali spreading factor (Table 2) of treated rice showed that maximum value was obtained by T₆ (3.99±0.15) and T₈ (3.99±0.11) however, minimum value was noted for T₁ (3.63±0.13). With the advancement in storage, a noticeable decrease was recorded in alkali spreading values. The values for the said trait decreased from 4.24±0.16 at 0 day to 4.03±0.21 and 3.66±0.14 at Day 30 and 60, correspondingly, whereas at 90th day, the noted value was 3.38±0.19.

Table 2. Pooled means for cooking and eating quality attributes of zinc fortified rice.

	Pooled means	Amylose Content (g/100g)	Alkali spreading value	Elongation ratio	Water absorption ratio	Volume expansion ratio
Storage	0 day	23.57±1.07	4.24±0.16 ^a	1.91±0.05 ^b	2.87±0.08 ^c	3.59±0.15 ^b
	30 days	23.32±1.12	4.03±0.21 ^a	2.12±0.08 ^{ab}	3.14±0.19 ^b	3.66±0.18 ^{ab}
	60 days	22.69±1.01	3.66±0.14 ^{ab}	2.24±0.09 ^{ab}	3.25±0.11 ^{ab}	3.73±0.11 ^{ab}
	90 days	22.16±0.99	3.38±0.19 ^b	2.39±0.07 ^a	3.40±0.17 ^a	3.87±0.17 ^a
Treatments	T ₀	23.14±1.04	3.75±0.14	2.16±0.09	3.17±0.14	3.69±0.11
	T ₁	22.41±0.79	3.63±0.13	2.09±0.10	3.07±0.13	3.63±0.18
	T ₂	22.48±0.82	3.71±0.16	2.15±0.10	3.14±0.15	3.65±0.12
	T ₃	22.15±0.93	3.70±0.16	2.10±0.09	3.11±0.11	3.65±0.19
	T ₄	22.91±0.95	3.85±0.19	2.16±0.07	3.15±0.12	3.71±0.16
	T ₅	23.19±0.86	3.94±0.12	2.19±0.08	3.19±0.07	3.74±0.15
	T ₆	23.16±1.02	3.99±0.15	2.21±0.09	3.23±0.18	3.79±0.16
	T ₇	23.31±0.97	3.87±0.17	2.18±0.09	3.18±0.08	3.78±0.12
	T ₈	23.70±0.88	3.99±0.11	2.25±0.08	3.26±0.19	3.82±0.14

Means sharing the same letter in a row are statistically alike, T₀ = Control, T₁ = Sodium alginate coated rice fortified with 25 ppm ZnSO₄, T₂ = Sodium alginate coated rice fortified with 45 ppm ZnSO₄, T₃ = Sodium alginate coated rice fortified with 25 ppm ZnO, T₄ = Sodium alginate coated rice fortified with 45 ppm ZnO, T₅ = Starch coated rice fortified with 25 ppm ZnSO₄, T₆ = Starch coated rice fortified with 45 ppm ZnSO₄, T₇ = Starch coated rice fortified with 25 ppm ZnO, T₈ = Starch coated rice fortified with 45 ppm ZnO.

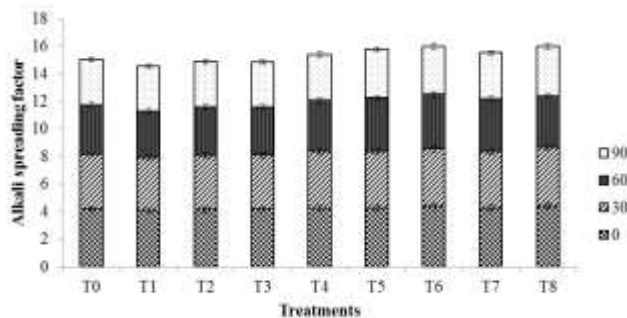


Figure 3. Variations in alkali spreading factor for various treatments during storage intervals; 0, 30, 60 & 90 days.

Elongation ratio: It was investigated that elongation ratio of treated rice was improved during storage. Maximum value showed in T₈ (2.25±0.08) followed by T₆ (2.21±0.09), T₅ (2.19±0.08), T₇ (2.18±0.09), T₂ (2.15±0.10), T₃ (2.10±0.09) and T₁ (2.09±0.10) respectively, whereas T₄ and T₀ (Control) exhibited same values for the said trait *i.e.* (2.16±0.07) and (2.16±0.09), accordingly. During aging, elongation ratio marked improvement amongst treated as well as non-treated rice samples. It was noted that elongation ratio differed from 1.91±0.05 at 0 day to 2.12±0.08, 2.24±0.09 and 2.39±0.07 at 30th, 60th and 90th day, accordingly (Table 2).

Water absorption ratio: The water imbibition ratio for biodegradable zinc carrier fortified rice was maximally recorded as 3.26±0.19 in T₈ while lowest as 3.07±0.13 in T₁. Over the storage period, water absorption ratio presented obvious improvement starting from 2.87±0.08 to 3.14±0.19, 3.25±0.11 and 3.40±0.17 at initiation to Day 30, 60 and 90, respectively (Table 2).

Volume expansion ratio: The expansion ratio for treated rice showed maximum value as 3.82±0.14 in T₈, while 3.63±0.18 in T₁ *i.e.* minimum recorded value. During storage, persistent increment was noted in volume expansion ratio, varying from 3.59±0.15 at initiation to 3.66±0.18, 3.73±0.11 and 3.87±0.17 at Day 30, 60 and 90, correspondingly (Table 2).

DISCUSSION

Of all the available foods, staple cereals are considered as good candidates for fortification. For instance, rice is consumed @ 150-300 g/cap/day in contrast to wheat flour <75 g/cap/day thus low level of salts are normally suggested for rice (Pee, 2014). In this context, inclusion of zinc salts equivalent to 20-50 & 42 mg/kg of corn flour & rice are suggested for safe fortification, respectively (Lucia *et al.*, 2014). Additionally, the proposed level of Zn by National Academy of Sciences is 2.2 mg/100g of products (Rubin *et al.*, 1975). However, the final recommended content of minerals & vitamins in the rice analogues should be within the range of 0.1-5% (Mishra *et al.*, 2012). From sensorial point of view, El Behairy *et al.* (2011) determined the good sensory attributes of fortified yoghurt with Zn sulphate @ 20 mg/kg.

Previously, Zn fortification was carried out in parboiled Super Basmati rice using ZnO and ZnSO₄ at varying levels from 100 to 500 mg/kg. Zinc fortified rice presented higher Zn retention 79.20-80.34% along with non-significant impact of storage. Furthermore, Zn content was analyzed using atomic absorption spectrophotometer, ranging from 4.3 to 8.5 and 4 to 8.5 mg Zn/100g of rice in ZnO and ZnSO₄ at different levels in contrast to unfortified equivalents 1.9 mg Zn/100g. Apart from this, non-significant effect of fortification was

observed on cooking aspects like volume expansion-, elongation- and water absorption ratio (Saleem *et al.*, 2014). Moreover, it was found that Zn & Fe possess higher storage stability in the rice with <10% losses whereas, loss of vitamin A have reached up to 82% during 3 months storage (Kuong *et al.*, 2016). Earlier, Prom-u-thai *et al.* (2011) studied the simultaneous effect of ZnSO₄+Fe-EDTA on polished parboiled rice as both Zn and Fe are normally missed in the diet of rice eaters. The results demonstrated that fortified rice can effectively raise Zn & Fe concentration up to 5 folds as compared to unfortified counterparts. Earlier, Porasuphatana *et al.* (2008) developed multiple fortified rice following the guidelines of FAO/WHO 2002 to meet the RDA of infants aged 6 to 8 months; 1.6 mg Zn, 4.5 mg Fe, 105 mg Ca, 0.08 mg thiamin and 11 µg folate per 20 g serving. They found non-significant losses during storage however, processing impacted negatively on minerals & vitamins and losses reached up to 2-11 & 20-30%, correspondingly.

In the current study, the mineral stability in the fortified samples was in accordance with the outcomes of Li *et al.* (2008). They prepared extruded plus multiple fortificants enriched rice prototypes. In their effort, storage stability with special emphasis on iron, zinc and vitamin-B were determined. The results depicted higher retention of zinc during 32 weeks of storage. Furthermore, they found soaking procedure suitable for basmati rice due to strong cell wall and high resistivity, whereas non-basmati rice suffered from cracks owing to their weaker cell wall structure that results in leaching of cell contents & higher solid loss. In another attempt, it was observed that Zn retention significantly depends on zinc solubility in freshly fortified rice. They found reduction in Zn bio-accessibility after 24 weeks of storage however, it still remained 14% higher than unfortified analogues (Saleem *et al.*, 2014). Later, Peil *et al.* (1981) recommended the use of hydroxypropyl methylcellulose and methylcellulose polymers (3:1) for optimal flexibility, strength, thickness and nutrient retention in rice fortification. They found retention of vitamin A, niacin, riboflavin, thiamin and iron by 70, 18, 21, 18 and 100%, respectively in 1 g of cooked rice in 100 mL water.

Conclusively, it is found that zinc fortification is preferred in staple diets like rice and wheat. In this sense, using salt @ 45 ppm could easily meet the recommended dietary allowance of an adult man *i.e.* 15 mg/300 g of rice per day. Alongside, edible coating could mask any alteration in sensory response. The results of the instant study has depicted that amongst the two salts; zinc sulfate and zinc oxide, Zn content is more in zinc oxide as compared to zinc sulfate as expected by previous researches.

Amylose content (AC) is a key determinant that influences other characteristics including alkali spreading factor, water absorption ratio, volume expansion ratio, *etc.* ultimately affects consumer preference and market value (Oko *et al.*, 2012). The amylose level serves as an inhibitor of swelling

property hence ensures fluffy and separated grains after cooking, whereas amylopectin is responsible for large structural changes leading to rupturing or leaching (Thumrongchote *et al.*, 2012).

Super basmati rice is a cross of Indica and Japonica resultantly most of the characteristics of the lies within the intermediate ranges; amylose content 20 to 25%, responsible for higher volume expansion (Imran *et al.*, 2014). Furthermore, the aged rice grain after cooking reduced stickiness to hardness ratio *i.e.* a desirable criteria of Indian consumers (Li and Jiang, 2015). Earlier, Butt *et al.* (2008) determined amylose content in super basmati rice as 22.91 g/100g. Alongside, they noticed reduction in amylose content over 16 weeks of storage. The quantitative decrement in amylose content is attributed to fractional decrease in its molecular weight during storage. Moreover, the amylose content in brown Super Basmati rice was reported as 23.37% (Asghar *et al.*, 2012). Previously, Champagne *et al.* (2010) scrutinized Pakistani premium rice varieties and ranked super basmati kernels at position 1 (best) followed by basmati 385. They elucidated amylose content for super basmati & basmati 385 as 23.4 & 24.9%, respectively.

The current outcomes are in harmony with the observations of Imran *et al.* (2014), they measured the amylose content of super basmati rice as 22.5%. It is further inferred that quality index value equal to or >2 represents “fine rice” and <2 as “coarse rice”. In this sense, Super Basmati and Basmati-385 are categorized as fine type with values 2.95 and 2.81. In addition, Rani and Bhattacharya (1995) determined that total amylose content is not directly proportional to insoluble amylose content. The rice variety with amylose content 28.5 & 25.8 showed 10.0 & 10.4% insoluble amylose, respectively. They also observed that soluble amylose is not related to rice texture, whereas insoluble amylose fractions indicate rice quality.

The alkali spreading value measures the compactness of rice endosperm (Yu and Wang, 2007). The extent of soaked milled rice spreading in alkaline solution measures gelatinization temperature. Rice with alkali spreading values (4.0-5.0) represents intermediate gelatinization temperature hence contributes partial disintegration (Rosniyana *et al.*, 2006). According to earlier scrutiny, alkali spreading factor was estimated in Super Basmati and Basmati-385 as 4.27 and 3.75 (Asghar *et al.*, 2012). Additionally, Imran *et al.* (2014) measured alkali spreading value of Super Basmati rice as 4.5. Elongation ratio of rice specifies grain shape resultantly influences on consumer acceptability. In this context, slender kernels are usually preferred by consumers *e.g.* length to breadth ratio of super basmati was reported as 1.54 (Imran *et al.*, 2014). Almost similar outcome was presented by Rashid *et al.* (2003), who analyzed elongation ratio of super basmati and reported the value as 1.87. Furthermore, Butt *et al.* (2008) quantified the elongation ratio for super basmati and basmati-385 as 2.29 and 2.15, respectively attributed to differences in

amylose content. They hypothesized that higher the amylose content, higher the capacity of starch granules to expand without disintegrating owing to the presence of H-bonding. Water uptake is an imperative tool for the determination of rice processing quality (Butt *et al.*, 2008). Previously, it is observed that fortified rice already carried open structure thus easily hydrated within short time. In contrast, extra water was employed for cooking Ca-fortified rice as Ca have the ability to maintains kernel integrity without excessive leaching of starch. However, different levels of Ca-salt do not significantly influence the hydration capacity (Lee *et al.*, 1995). In another study, good retention of vitamins after cooking is attributed to high diffusion or absorption capacity of vitamins into the interior of the rice grain (Kyritsi *et al.*, 2011). The previous researchers found different water uptake based on different varieties and amylose content. It was found that Koshihikari had lowest amylose content with maximum water uptake, whereas opposite was observed in case of Doongara, among the three cultivars; Koshihikari, Kyeema and Doongara. Furthermore, it is proposed that leached or swelled starch components increases water holding capacity leading to starch hydration in cooked rice (Zhou *et al.*, 2007). In this regard, Butt *et al.* (2008) reported water absorption ratio of super basmati and basmati-385 as 3.21 and 3.06, respectively. They found increment in water absorption of rice with progression on storage owing to the formation of hard amylose-lipid complexes, requiring more water for cooking as hard rice is less prone to disintegration. Likewise, numerous researchers supported this fact that aged milled rice possess significantly higher water uptake due to stronger cell wall of rice grains i.e. resistant to swelling/disruption on cooking. One of the groups of scientists, Santhi and Vijayakumar (2014) related higher water absorption capacity with protein content as well as with starch & cellulose content.

The volume expansion ratios in Super Basmati and Basmati-385 were analyzed as 4.42 and 3.83, respectively (Butt *et al.*, 2008). The volume expansion ratio is linearly related with amylose content (Asghar *et al.*, 2012). Furthermore, it was observed by Rosniyana *et al.* (2006) that more aged rice presents higher volume of expansion because aging ensures hardening resiliency of cell walls, resisting high pressure inside the cell. According to a previous study, volume expansion ratio in super basmati, basmati 2000, Irri-6 and KS-282 were ranged from 3.94 to 4.29 (Santhi and Vijayakumar, 2014). Moreover, Khan *et al.* (2009) determined cooking aspects of super basmati such as water absorption ratio (2.95), volume expansion ratio (3.71) and elongation ratio (1.91). One of their peers, Akram (2009) studied the cooking and eating characteristics of super basmati rice including kernel length (7.68 mm), length to breadth ratio (4.4), kernel breadth (1.7 mm), cooked kernel length (15 mm), elongation ratio (2), amylose content (23.44%), alkali spreading value (4.7), intermediate gelatinization temperature, extra-long kernel

size, slender kernel shape and strong aroma. Decisively, this variety is considered superior over other basmati rice varieties. Overall, the previous researchers supported the notion that water absorption-, elongation- and volume expansion ratio increases over the storage duration along with decrement in solid loss (Keawpeng and Venkatachalam, 2015).

Lastly, it is deduced that amylose decreases during initial stages of storage but obvious increment is expected over prolonged storage. The initial decrement could be due to fractional decrease in amylose content. Then, question arises how water absorption, volume expansion and elongation ratio increases during storage. This might be linked with increase in insoluble amylose and formation of amylose-lipid complexes during aging hence considered as the main determinants for hard and strong texture.

Conclusions: It is deduced that zinc fortification using rice as fortification vehicle is a preferable choice. In this sense, employing salt @ 25 ppm could impact positively towards hedonic response, whereas zinc salt @ 45 ppm could easily meet the recommended dietary allowance of an adult man i.e. 15 mg/300 g of rice per day. Alongside, edible coating could mask any alteration in sensory response and improve the stability of fortificants. Comparison of zinc sulfate and zinc oxide showed higher Zn content in zinc oxide based prototypes over zinc sulfate. Considering cooking and eating perspectives, it is started that amylose decreases during initial stages of storage but obvious increment is expected over prolonged storage. The initial decrement could be due to fractional decrease in amylose content. Then, question arises how water absorption, volume expansion and elongation ratio increases during storage. This is linked with increase in insoluble amylose, formation of amylose-lipid complexes during aging and stronger cell wall in response to starch gelatinization & maintenance of hexagonal shape, ensuring hard texture.

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