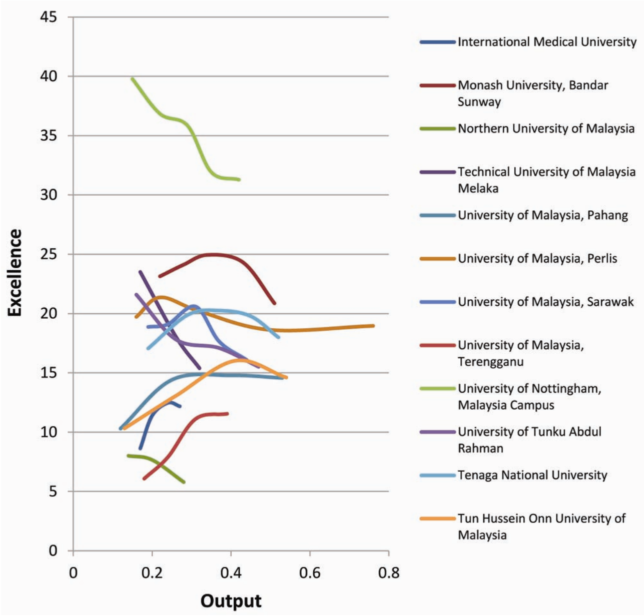

Figure 2. Excellence–output trajectories for the group of low-output universities.

The present study confirms the generally accepted notion that UM and USM are the leading public universities. These two universities are the oldest in Malaysia, established in 1959 and 1969 respectively. In fact, both these universities were ranked at the top 200 in the first THES-QS Best Universities ranking in 2004. UM continues to be ranked in the top 200 of the 2014 QS Best Universities ranking.

In 2012, UM became the first university to be ranked in the Shanghai Jia Tong AWRU top 500 universities. It is now ranked in the 301–400 list of the AWRU 2014. In 2014, the USM was included in the top 500 for the first time.

It is expected that private universities will continue to strengthen their research productivity to enhance their image locally as it will be a good marketing strategy.

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Effect of processing condition on the quality and beany flavour of soymilk

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Soymilk is a water extract of soybean and contains good-quality proteins, fat, minerals and phytochemicals. Regular use of soymilk enhances and protects human health. However, soymilk prepared by traditional method of cold-water grinding has a characteristic beany flavour which may not be acceptable to all consumers. This flavour could be minimized using appropriate processing technology. The present study shows that soymilk with almost negligible flavour could be produced using hot-water grinding and deodorization. Shelf-life of soymilk is about a week when it is pasteurized and stored in a refrigerator. The sensory quality parameters such as appearance, flavour, taste and overall acceptance of soymilk prepared by hot-water grinding followed by deodorization were good, indicating high consumer acceptance.

Keywords: Beany flavour, deodorization, lipoxygenase, phytochemicals, soymilk.

SOYMILK is a water extract of soybean, a grain legume and one of the oldest known food sources of the world to human beings. It contains good-quality ingredients for food, feed and pharmaceuticals and other industrial applications[1,2]. Phytochemicals present in soybean are health-promoting. Soybean is nutritious, economical and eco-friendly. The edible portion of soybean contains about 40% protein, 27% complex carbohydrates, 20% oil, 8%

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moisture and 5% minerals. Soy protein is the best plant protein and its quality is equivalent to that of livestock proteins in terms of protein digestibility corrected amino acids score (PDCAAS) and it is least expensive (Rs 100–150/kg of soy protein, whereas pulse proteins cost Rs 300–350/kg of protein and that from livestock sources is Rs 500–1800/kg of protein)[3–6]. As of now the world soybean production is about 240 MT (million tonne) and that of India is about 13 MT. The five major soybean-producing countries of the world are USA, Brazil, Argentina, China and India[7,8].

One kilogram of dry soybean yields 4–6 litres of milk containing about 90% water, 3.5% protein, 2% fat and 4.5% non-lactose carbohydrate and phytochemicals. Special features of soymilk are low cost (Rs 15–20/litre), good nutrients and its suitability to lactose-intolerant people. It is the base material for making soy paneer (tofu), soy yoghurt and other dairy analogies. Soymilk can be used for feeding infants and as supplements to diets of the pre-school children, young adults and old people[9,10].

Soymilk has a characteristic beany flavour which may not be acceptable to all consumers[10–12]. The flavour can be minimized/masked using food flavour like cardamom, ginger, fruits (mango, apple, litchi, etc.) and chocolates while making soymilk as a beverage. The flavoured soymilk when served chilled found to be popular in countries where soymilk has been introduced recently[8].

The beany flavour in soymilk is on account of the presence of lipoxygenase enzymes in soybean which become active as soon as the cotyledons are broken and enzymes come in contact with water, oxygen and lipids; these combine together to give the beany flavour[13–19] as follows:

$H_2O + O_2$ + lipids + lipoxygenase $\rightarrow$
Beany flavour causing volatiles such as methanol, acetaldehyde, ethanol, hexanol, hexanal, pentanol, etc.

Lipoxygenase is heat-sensitive and gets inactivated at higher temperatures. Traditionally beany flavour in soymilk has been controlled/minimized by inactivating the enzymes through heating, or altering the pH of the aqueous medium in which soybean seeds are disintegrated[14,20–22]. Beany flavour in soymilk can be tackled by partially inactivating the enzyme and then removing the remaining flavour by deodorization and masking of the residual flavour by natural flavouring agents. Vacuum flash deodorizing system is a technically advanced device for removing/minimizing flavour from slurry or liquid food products[23–25]. The major advantage of this device is that it is a continuous operation, yields an excellent neutral/bland product and the level/degree of deodorization can be controlled[8,10]. The present communication discusses various methods of minimizing beany flavour is soymilk and the comparative performances in terms of physical, biochemical and microbiological aspects and suggests how to prepare soymilk with least beany flavour, good nutrition and low cost.

Soybean variety JS-335 grown at the farm of Central Institute of Agricultural Engineering, Bhopal was used for the study. The harvested soybean was cleaned, dried and stored in plastic containers at 4°C until it was processed for making soymilk.

Six different methods, namely traditional oriental method, hot-water grinding method, Illinois method, rapid hydration hydrothermal cooking method, airless grinding method, and deodorization method were used for the production of soymilk (Figure 1). A brief description of the different processes is as follows:

In traditional oriental method (TOM), soybean was soaked at room temperature for 4 h was ground and cooked. Cooking of soy-slurry/pulp with added water (6.0 kg/kg of dry soybean) was done for 20 min at 82°C. This was followed by filtering of cooked slurry using two-layer muslin cloth to separate out okara. This process is also known as cold-water grinding method.

In hot-water grinding method (HWGM), soybean was soaked at room temperature for 4 h and then ground using boiling water to maintain soy slurry temperature of 90°C or more. This was followed by cooking for 15 min at 90°C or above and then filtering with two-layer muslin cloth to separate out soymilk and okara. This process reduces the beany flavour by inactivating lipoxygenases during grinding at 90°C and above.

In illinois method (IM), soybean was first soaked for 12 h in 0.5% $NaHCO_3$ solution, drained and then boiled in fresh 0.5% $NaHCO_3$ solution for 30 min, drained again and ground in water at room temperature. The soy-slurry was then heated to 90°C and filtered to remove okara. The soymilk thus produced has bland flavour.

Figure 1. Soymilk prepared using different methods. TOM, Traditional oriental method; HWGM, Hot-water grinding method; IM, Illinois method; RHHM, Rapid hydration hydrothermal method; AGM, Airless grinding method; DM, Deodorization method.

In rapid hydration hydrothermal method (RHHM), soybean was ground into flour and made into slurry using hot water and then pressure-cooked for 30 sec, cooled and adjusted to 9% solid with water and centrifuged to get the soymilk.

In airless grinding method (AGM), soybean was soaked for 4 h at room temperature and ground under airless condition at 120°C for 20 min, cooked and then filtered using two-layer muslin cloth to separate out milk and okara.

In deodorization method, a spiral-type soymilk deodorizer of 100 l/h was developed. The principle of the deodorizer is that under partial vacuum soymilk is passed through the cylindrical drum mounted with spiral plate assembly for the flow of milk to have maximum retention time and exposure surface area of milk during its flow for the production of more volatiles and sucking of these off-flavour causing components. The deodorizer consists of a cylindrical drum, spiral channel assembly, vacuum system, soymilk inlet system, feeding dome and outlet cone. The minimum length to diameter ration ($L : D$) of the cylindrical system is 2.8 : 1 for efficient discharge of fume. In the flow zone, 5 mm holes in two rows of spiral plate connected with pipes are provided for splashing of milk and initiation of further production of volatiles. The developed deodorizer was fitted to the existing mini soymilk plant (Figure 2). Soymilk prepared from traditional oriental method and hot water grinding method was used for the deodorization study. The deodorized soymilk was taken for quality analysis and sensory evaluation.

Soymilk produced using soybean : water ratio 1 : 6 by the above six different methods was analysed for its physico-chemical, proximate, hydroperoxide, antioxidant activity, lipoxygenase visual assay, microbiological qualities and sensory parameters using standard procedures. Various quality parameters of soymilk and procedures used for their determination are as follows:

Figure 2. Testing the developed deodorizer with soymilk plant.

Soymilk yield was determined by weighing the soybean slurry obtained immediately after wet grinding and soymilk obtained after filtration. Soymilk yield is expressed as the ratio of soymilk and slurry.

Physical characteristics like solid content, pH value and conductometric analysis of soymilk were done using standard techniques and procedures.

Protein, fat, carbohydrate and ash contents of soybean and soymilk were determined in triplicate using standard method[26].

Hydroperoxide was determined using thiobarbituric acid reactive species assay[27].

DPPH assay is a stable free-radical in a methanolic solution. In its oxidized form, the DPPH radical has an absorbance maximum at about 520 nm (ref. 28).

Lipoxygenase-catalysed oxidation and chemical oxidation may also be indirectly responsible for the formation of rancid off-flavour. The initial enzymatic reaction catalysed by lipoxygenase only involves the activation of substrate and incorporation of O_2 to form hydroperoxide. A visual procedure for the MBB method was modified from Suda *et al.*[29].

The dye substrate, MBB reagent, was prepared by first weighing 154.25 mg of dithiothreitol and transferring it to a 125 ml flask. The following additional components were then added to the flask: 25.0 ml 0.2 M sodium phosphate buffer (pH 7.0), 5.0 ml 0.1 millimolar (mM) methylene blue, 5.0 ml acetone and 9.0 ml 0.01 M linoleic acid substrate. After adding all the components, the mixture was swirled. This dye substrate was adequate for 20 samples.

The procedure is as follows: First 10 ml soymilk sample was taken in the centrifugal tube and centrifuged at 10,000 *g* for 15 min for collection of supernatant. The assay was carried out by mixing 0.6 ml supernatant and 2.0 ml MBB reagent in a clean test tube. A positive test was indicated by blue colour and score with respect to disappearance (bleaching) of blue colour within 2 min.

For estimating the total bacterial count, the soymilk samples were placed in a polypropylene container. Nutrient agar was used as the growth medium; it was prepared according to manufacturer's specifications. The standard tenfold serial dilution technique was employed to dilute each soymilk sample up to ten levels. The plates were then inoculated with 1 ml of the ten dilutions and then incubated at 37°C for 24 h, after which the number of viable cells was counted using a digital colony counter. All plates were triplicated, incubated at 37°C for 48 h, and viable cell numbers were determined as colony forming units (CFU) per ml.

Soymilk prepared using different methods was kept in an airtight container and stored at two different conditions for shelf-life studies. One group was stored at room temperature (23° ± 2°C) and the other at refrigeration temperature (4°C). Shelf-life studies were carried out immediately after preparation (0 h) and every 12 h thereafter, until it was spoiled. Bad odour, bad taste and separation of soymilk for its shelf life were considered based on microbial population.

Soymilk was also evaluated for taste, texture, flavour, odour, appearance and overall acceptability by a panel of nine trained judges using a nine-point hedonic scale. The mean score of 5 was considered as acceptable. The response was critically analysed[30].

An experiment was conducted to study the effect of different methods used for preparation of soymilk and their effect on physio-chemical parameters, proximate composition, total bacterial count, hydroperoxide level and antioxidant activity. Completely randomized design (CRD) was used in the experiment. The experimental data were analysed using GLM procedure available in the statistical analysis software. The significance of different methods, their pairwise comparison and estimation of coefficients were carried out. The pairwise comparison was performed using Tukey's Studentized Range Test.

The physio-chemical study of soymilk quality obtained from six different processes indicates variation in solid yield content (%), protein yield, conductivity (mS), total dissolve solid (ppm) and pH (Table 1). The solid content of soymilk for all the samples varied from 5% to 8%. The highest solid content was in soymilk prepared by traditional oriental method and it could be a result of less solubilization at the time of grinding. The highest pH (7.39) was found in the Illinois method, which may be attributed to soaking and cooking of soybean in the presence of sodium bicarbonate. It is beneficial for inactivation of lipoxygenase enzyme and trypsin inhibitor activity at higher pH. The lipoxygenase activity and trypsin inhibitor activity were found to decrease with increase in temperature and pH. Highest protein yield (93%) was observed in soymilk prepared by IM. A comparative study of different biochemical parameters in different methods indicates that the highest solid content is observed in TOM and lowest in IM, and the conductivity of IM was found to be maximum because of higher solubilization of solid and formation of higher active particles. Higher value of total dissolved solids was found in TOM, compared to other methods, and the protein yield was minimum in this method. Protein yield was maximum (92–93%) in IM and RHHM. The protein extraction was higher in IM and RHHM due to higher membrane protein solubilization during high pressure and soaking in the presence of sodium bicarbonate. In the case of TOM, the protein yield was low due to room temperature grinding not resulting in much solubilization and low rate of extraction.

The proximate composition of soybean seeds used for the preparation of soymilk was moisture content (6.17%), protein content (34.51%), fat (17.09%), ash content (5.65%) and carbohydrate (36.58%). Table 2 shows the proximate composition of soymilk sample prepared by different methods. The moisture content of different soymilk samples was found to be in the range 89–92%. The protein content ranged from 2.81% to 3.19%. The protein content of IM, AGM and DM was higher in comparison to other methods. The fat content was found to vary from 2.12% to 2.46%. The carbohydrate content of IM was lower compared to other methods due to longer time of soaking and cooking at several steps, which hydrolysed the carbohydrate, especially soluble sugars. Similar result was also reported by Wilkens *et al.*[31] and Shurpalekar *et al.*[32].

The soymilk prepared by TOM has strong beany flavour in comparison to soymilk prepared by other methods. In case of TOM, the formation of hydroperoxide in the presence of polyunsaturated fatty acid, air, water and lipoxygenase enzyme resulted in a conducive atmosphere for the production of higher hydroperoxide.

The more the production of hydroperoxide, higher is the level of beany flavour. The level of beany flavour and flavour quality was found to improve in soymilk prepared by IM, RHHM, AGM and DM. The lowest level of beany flavour compounds in these methods indicates lower level of hydroperoxides and reduced activity of lipoxygenase enzymes. The hydroperoxide content of normal soybeans (those with lipoxygenase activity) ranged from 63.5 to 83.6 nmol/g. The hydroperoxide content of soymilk showed variation with soymilk preparation methods. The hydroperoxide content of soymilk produced from different methods ranged from 4.73 to 17.50 nmol/g. Results obtained in the present study are similar to those found in the literature[18,33]. It has been reported that the *n*-hexanal content, the major constituent of the beany flavour of soymilk, is directly proportional to that of hydroperoxide[33]. The beany flavour of soymilk prepared by all lipoxygenase-lacking soybeans is less than that of soymilk made from normal soybeans[34]. It is found that soymilk with minimal beany flavour can be prepared if the hydroperoxide content is approximately 5 nmol/g.

The hydroperoxide content in IM and deodorization method was lower in comparison to other methods. The hydroperoxide content of soymilk in the control group was 17.5 nmol/g. The hydroperoxide content of heat-treated and sodium bicarbonate-treated soybean in IM was appreciably lower. The AGM also showed lower levels of hydroperoxide in comparison to grinding with mixer-grinder. The soaking timing and duration of grinding in the absence of air were found to be more effective in reducing hydroperoxide in soymilk. Based on the above results, it can be inferred that if normal soybeans are blanched in boiling water after being soaked and swollen, the hydroperoxide content can be reduced without markedly diminishing the content of protein or solid matter, thus reducing the beany flavour[10,35]. There was

Table 1. Physio-chemical analysis of soymilk prepared using different methods

Method of soymilk preparation	Solid yield (%)	Protein yield (%)	Solid contents (%)	Conductivity (mS)	TDS (ppm)	pH
Traditional oriental method	61	72	8.0	3.03	1520	6.52
Hot-water grinding method	65	82	7.4	1.54	776	6.75
Illinois method	88	93	5.2	3.23	1620	7.39
Rapid hydration hydrothermal method	86	89	6.8	2.93	1453	6.29
Airless grinding method	76	87	7.2	2.73	1372	6.31
Deodorization method	77	85	7.4	2.63	1357	6.40

Table 2. Proximate composition of soybean and soymilk prepared using different methods

Method of soymilk preparation	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Carbohydrates (%)
Traditional oriental method	89.20	2.81	2.15	0.41	3.43
Hot-water grinding method	90.50	2.93	2.23	0.39	3.95
Illinois method	91.51	3.19	2.36	0.49	2.46
Rapid hydration hydrothermal method	91.16	2.94	2.39	0.42	3.15
Airless grinding method	90.50	3.12	2.27	0.33	3.78
Deodorization method	91.15	2.98	2.19	0.33	3.35

73.6% reduction in hydroperoxide content of soymilk prepared from deodorization method compared to TOM. However, 68% reduction of hydroperoxide was observed in soymilk prepared by IM. Deodorization method is a chemical-free technique for minimization of beany flavour, resulting in higher acceptability. The antioxidant activity of soymilk samples was found maximum in TOM in comparison to other methods. This may be attributed to processing techniques used for soymilk preparation. In the traditional method, soymilk is prepared by grinding at room temperature resulting in minimum loss of antioxidants. However, in other methods either heat, chemical or pressure treatment is responsible for higher loss of antioxidants, giving lower values.

The lipoxygenase activity was found in all selected processes for soymilk preparation; it was higher in TOM and lower in deodorization method and IM. The lox visual assay was determined to observe the disappearance of dye colour in soymilk sample. The lesser time required for colour disappearance indicates higher lipoxygenase activity. The colour disappearance is measured in 1 to 6 min for visual assay that is achieved in traditional method indicating higher lox activity. However, the colour disappearance in other methods took more than 30 min, suggesting lower activity of lipoxygenase enzyme and unfavourable conditions for the production of hydroperoxide. The percentage of original MBB activity remaining in the samples decreased with blanching time. Toyosaki[36] proposed a mechanism for the MBB reactions. Methylene blue was hypothesized to be bleached when the hydroperoxide was produced by the removal of hydrogen. Suda *et al.*[29] also proposed that a redox reaction was involved in the bleaching reaction, because methylene blue is a redox indicator.

Raw soymilk and pasteurized soymilk were used for microbial load counting. Table 3 shows the results of microbial examination of soymilk prepared using the six methods. Maximum plate count was observed in raw soymilk TOM because of less control measured during the production process. However, lower microbial count in other methods, especially IM and RHHM, indicates unfavourable condition for microbial growth (Table 3). In pasteurised milk no bacterial count was observed in soymilk prepared from various methods and storage at 4°C (ref. 37).

In shelf-life studies, all samples except those TOM remained stable emulsion for both raw and pasteurized conditions. The beany flavour of raw soymilk became stronger during the second day of storage at 4°C. By the fourth day of storage, the odour of other samples became stronger and moulds had started to grow. The pasteurized and refrigerated soymilk had no change in taste and odour after one week of storage, and when the samples were examined microbiologically on the sixth day, there was no growth. This indicates that the pasteurization temperature and time are adequate for packaging and storing of soymilk, regardless of the production method.

The sensory quality attributes (appearance, flavour, taste and overall acceptability) of soymilk samples were evaluated using nine-point hedonic scale (Table 4). It was found that the sensory quality of traditional soymilk was just good. However, the quality parameters as well as the overall acceptability of soymilk prepared from deodorization and Illinois methods was good, as indicated from the

Table 3. Total bacterial count of raw and pasteurized soymilk using different methods

Method of soymilk preparation	Raw soymilk (cfu/ml)	Pasteurized soymilk (cfu/ml)*
Traditional oriental method	9.60×10^5	No bacterial growth
Hot-water grinding method	7.60×10^5	No bacterial growth
Illinois method	3.80×10^5	No bacterial growth
Rapid hydration hydrothermal method	5.30×10^5	No bacterial growth
Airless grinding method	4.13×10^5	No bacterial growth
Deodorization method	4.11×10^5	No bacterial growth

*Analysis was performed after 7 days of storage at 4°C.

Table 4. Sensory evaluation of soymilk samples

Method of soymilk preparation	Appearance	Flavour	Taste	Overall acceptability	Beany flavour	Lox visual assay test (1–6 min)
Traditional oriental method	6.3	5.5	6.0	6.0	Strong	7
Hot-water grinding method	7.2	6.25	6.76	6.50	Improved	NA
Illinois method	7.5	7.29	7.35	7.30	Least	NA
Rapid hydration hydrothermal method	6.5	6.19	6.9	6.70	Less	NA
Airless grinding method	7.0	6.72	7.12	6.55	Less	NA
Deodorization nethod	7.7	7.44	7.50	7.50	Least	NA

Table 5. ANOVA of hydroperoxide level and antioxidant activity of soymilk prepared using different methods

Source	Degree of freedom	*P* value	
		Hydroperoxide	Antioxidant
Model	5	<0.0001	<0.0001
Traditional oriental method		<0.0001	<0.0001
Hot-water grinding method		<0.0001	0.02
Illinois method		<0.0001	0.0001
Rapid hydration hydrothermal method		<0.0001	<0.0001
Airless grinding method		<0.0001	<0.0001
Deodorization method		<0.0001	0.0001
Error	12		
Total	17		
R^2		0.99	0.84
CV		1.01	7.54

Table 6. Pairwise comparison of hydroperoxide level and antioxidant activity of soymilk prepared using different methods

Method	Means	
	Hydroperoxide	Antioxidant
Traditional oriental method	17.61	41.66
Hot-water grinding method	10.34	36.33
Illinois method	5.61	30.66
Rapid hydration hydrothermal method	6.77	28.66
Airless grinding method	7.44	29.00
Deodorization method	4.76	30.33
Mean significance difference	0.24	6.78

sensory score data. The sensory analysis indicated that soymilk prepared using Illinois and deodorization methods was found to be creamy, with bland taste, least odour and no crystalline solids. The sensory quality of soymilk prepared using IM indicated that sodium bicarbonate not only had an effect of softening the soybean, but also removed the beany flavour and left the soymilk blend. The deodorized soymilk operated at partial vacuum, sucked and removed the volatile compounds responsible for beany flavour without the use of any chemical treatment, giving a sweet taste and flavour and resulting in higher consumer acceptability.

The effect of different methods of soymilk preparation on physio-chemical parameters such as solid yield, protein yield, solid contents, conductivity, total dissolve solids, pH, proximate composition (moisture, protein, fat, ash and carbohydrate), and hydroperoxide level was found to be significant at 1% level. Table 5 presents ANOVA of hydroperoxide level and antioxidant activity of soymilk prepared by different methods. The statistical analysis indicates that these parameters of soymilk vary significantly with different methods of preparation. Also R^2 and coefficient of variation (CV) for each parameter indicate goodness-of-fit of the model, and CV of the variable under study was found to be very low (Table 5). The pairwise comparisons and minimum significant difference (MSD) at $P = 0.05$ level of significance for all the quality parameter were found to be different for different methods of soymilk preparation. It can be seen from Table 6 that the hydroperoxide level and antioxidant activity vary significantly for different methods of soymilk preparation according to minimum significance difference.

The overall comparative physico-chemical qualities of soymilk prepared by Illinois and deodorization methods were found optimum and acceptable. The hydroperoxide content, responsible for beany flavour was minimum in soymilk prepared by deodorization method followed by Illinois, rapid hydration hydrothermal, airless grinding, hot water grinding and traditional oriental methods. The shelf life of raw soymilk prepared by traditional oriental method and stored at 4°C was only one day, whereas that of raw soymilk prepared by other methods was 2–3 days. There was no change in taste and odour of pasteurized and refrigerated soymilk at 4°C up to seven days of storage. The organoleptic score of soymilk prepared by Illinois and deodorization methods was highest indicating good taste, flavour and acceptability among the people.

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Agronomic fortification of rice and wheat grains with zinc for nutritional security

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Zinc (Zn) deficiency is the most widespread micronutrient deficiency in crop plants and humans. Low intake of Zn through diet appears to be the major reason for the widespread prevalence of Zn deficiencies in human populations. Application of Zn fertilizer in soil having low Zn increased the grain yield in wheat up to 6.4–50.1%. However, soil Zn application increased the grain yield of rice only up to 7.2–14.8%. Soil having sufficient Zn had no or little effect on grain yield with soil Zn application. The application of foliar Zn with or without propiconazole resulted in significant increases in grain Zn irrespective of soil Zn status. Application of foliar Zn along with propiconazole at earing and milk stages proved beneficial in increasing grain Zn content in both rice and wheat. Hence agronomic biofortification is possible and could be considerably economical if used along with a fungicide depending upon appearance of a disease.

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THE foodgrain production of the Indian subcontinent improved tremendously after the introduction of high-yielding, dwarf, fertilizer-responsive varieties of rice and wheat during 1966–68, progress in manufacture and consumption of chemical fertilizers, increase in irrigation facilities and development of rural infrastructure[1]. Rice and wheat constitute nearly two-thirds of the energy needs of humans in India[2]. Rice–wheat cropping system occupies about 10 million ha in the Indo-Gangetic Plains of India and is spread over the states of Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal[1]. This cropping system has led to a significant decline in the area under legumes, which are a rich source of proteins and micronutrients. Till recently, the three major micronutrient deficiencies recognized globally were vitamin A deficiency leading to blindness, iron deficiency causing anaemia, and iodine deficiency responsible for goitre. Deficiency of zinc (Zn) has received global attention recently. Graham and Welch[3] reported that 50% of the soil used for cereal production in the world contains a low level of plant available Zn, which reduces not only grain yield but also nutritional quality. Zn deficiency in humans causes a wide range of health complications, including impairment in the immune system, learning ability and physical growth, and increase in mortality and infections[4]. Children are particularly more sensitive to Zn deficiency, which has been shown to be a major cause of death among children all over the world. It is responsible for nearly 450,000 deaths in children under the age of 5 years, which corresponds to 4.4% of the deaths among children less than 5 years of age globally[5].

Zn has been found useful in improving yield and yield components of wheat[6–8] and rice[9]. It is high time that along with food security due attention should also be given to adequate micronutrient nutrition. Soil and foliar Zn fertilization has shown good response in a number of crops including rice and wheat. Development of a new variety by conventional plant breeding is genetic biofortification, whereas agronomic biofortification is enrichment of micronutrients in the grains by application of appropriate fertilizers. Fertilization approach is cheaper, faster and safer and can be applied to a number of crops. The