

Bio-processing of wheat – untapped opportunities for value added products

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Abstract

For more than a century wheat improvement activity in India has been focusing on enhancing the per hectare productivity under varying environments and growing conditions. Much success has been achieved in breeding high yielding stress resilient varieties with grain quality satisfying the domestic needs. From a mere 9.0 million tons total production during 1947 when India was bifurcated; in 2012 about 93.8 million tons of wheat grain was harvested. In addition to this a huge amount of straw or biomass was also harvested. Till few decades ago, this biomass was utilised as bovine feed to serve more as roughage. Now, with a high degree of farm mechanisation and adoption of the rice wheat system, this resource is burnt in the field so that the field is vacated quickly to transplant rice. The present surging grain surplus and the fall in demand for the biomass has created a need to revisit the wheat improvement activities and to explore the possibility of positioning the wheat crop for total bio-processing usage at least by 2030. This will then necessitate bringing about a substantial research re-orientation to create a win-win profit situation to both the farmer and the bio-processing industry.

Key words: Wheat, *Triticum* spp., bio-processing, focus on new traits, and biomass usage

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Introduction

Punjab that is endowed with ideal wheat growing climate, captive irrigation, and innovative farmers was exporting each year a million ton or more wheat to the UK. But by the time the First World War started, wheat exports from Punjab almost completely stopped. Soon, free India ended as a net importer of 10.0 million tons (mt) of wheat during mid-1960's from the US under the PL480 grants. The Indian Punjab played a key role in ushering the Wheat Revolution of the 1970s enabling India to emerge once again (by 2010) as a regular exporter of wheat. As per the Economic Survey of the Government of India in 2011-12, a record wheat harvest of 93.8 million tons was achieved due to better varieties, adoption of good agronomic practices, farm mechanisation, communication and extension network, remunerative minimum support price (MSP) and the pro-active policies of the Government. India is now comfortably placed to produce even 109 million tons of wheat by 2020. Despite all this, pessimism and a gloomy picture has been painted regarding producing adequate wheat by 2030 (Brown, 1996; Stokstad, 2007; Singh *et al.*, 2008, 2011).

Wheat revolution is now sweeping central zone

For four decades the North West Plain Zone (NWPZ) was the prime mover of the wheat revolution and contributor

towards wheat self-sufficiency. Often, it was at the cost of exhausting the endowed natural resources of the area, maximising cropping intensity, mono-cropping of rice / wheat and this resulted in the depletion of soil resources (Prasad and Nagarajan, 2005). But then, in the eyes of the farmer, the economics of MSP and assured procurement of wheat in the NWPZ; and the world price for the aromatic long grain Basmati rice did weigh more than the consequence. This lure for the R / W system in Punjab, compelled policy makers issue a binding Government directive to ban transplanting of rice before June/ July, to avoid over irrigation during the hot summer and go-in for soil test based fertiliser usage. Also states where wheat yields were low such as Rajasthan, Gujarat and Madhya Pradesh (MP) revised their policies; popularised sprinkler irrigation for wheat, replaced the old varieties with better ones and promoted the application of balanced fertilisers to maximise wheat production (Anonymous, 2012b).

This overall improvement of productivity in Central Zone (CZ) contributed towards achieving a record wheat production in 2011-12. Wheat harvest of MP increased substantially during 2007 to 2012 and such a gain in production is less obvious in Bihar (Figure 1). Therefore, many grain procurement centres became active in Central India mopping the surplus harvest for overseas trade and to sell in the Peninsular Zone. Still there is considerable scope to increase wheat production in CZ and in the North Eastern Plain Zone (NEPZ). If the current trend and rational policies are meticulously followed, India will be soon emerging as the largest producer of wheat in the world.

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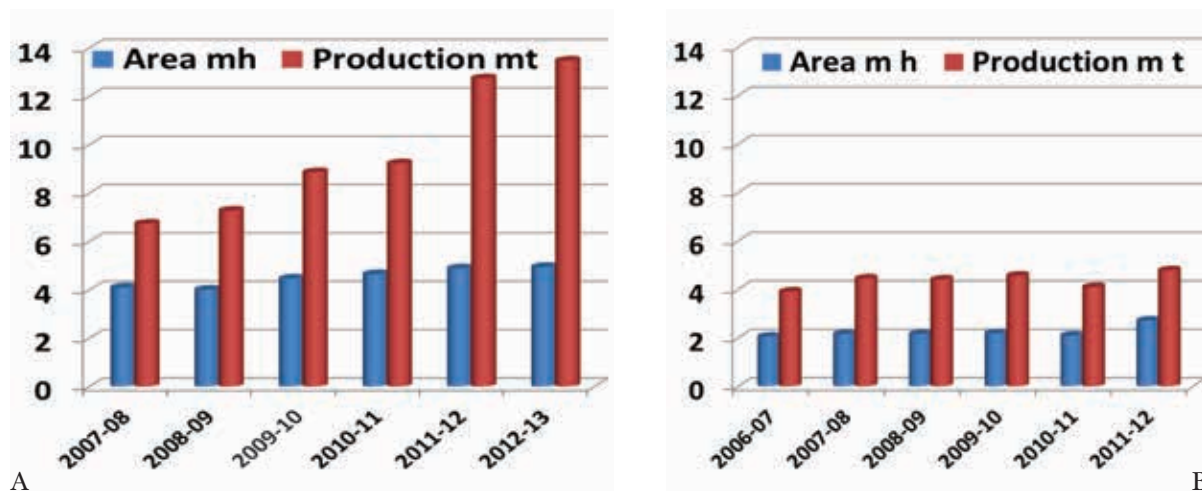


Fig 1. Wheat area and production (mt) in Madhya Pradesh (A) and Bihar (B) during the last few harvest seasons.

The question is, even after harvesting less wheat compared to the earlier predicted needs, there is a swelling in the size of the buffer stock. And if India is to produce more, then for whom we are producing and at what cost? Even the demand for public distribution under the Food Act which may soon come under practice will not lift the mounting surplus wheat. Therefore, the Indian wheat program should present a white paper as to what is the cherished future goal of the Indian wheat programme. It can possibly be as below:

New trade opportunities: In all likelihood, the western borders of India may soon enable a trans-border wheat trade. Then opportunities for moving higher volume of grain from India by surface transport to Iran, Iraq, Pakistan and Central Asian nations may happen. Notwithstanding this, Punjab should build grain silos in Mundra, Kandla, Vizag ports for rapid and effective trans-oceanic grain trade. Linked with this is the type of wheat that the overseas client would demand from India. Then from now on, the NWPZ should breed and grow wheat varieties specifically meant for SE Asia, for the Near East, Chinese market etc. Such varieties must be grown in earmarked areas so that pre-harvest inspection can be undertaken by the representatives of the importing countries / companies. The Sanitary and Phyto-Sanitary (SPS) issues must form the broad outline for any foreign trade and must be WTO compliant. Australia reshaped its wheat breeding programme more than a decade ago and now extensively grows specific wheat varieties for trade with East Asia. In 1990s Australia developed white-wheat varieties specifically tailored to produce high-quality Asian noodles to dominate the Chinese market (Popper *et al.*, 2006).

Wheat varieties with enhanced quality are important for the future of Punjab's wheat trade and the current programme including the variety identification and popularisation procedure calls for a review and reshaping. There is a felt need to execute structural changes in the

All India Coordinated Wheat Improvement Project (AICWIP) to promote state and sub-zone releases of wheat varieties that possess trade and product development traits. The Girkin cultivation in Karnataka for overseas market is an example of how to do things. Marking out the "Wheat-Export Zones" is one way of promoting organised wheat trade. There must be a clear vision and policies to enable Punjab capture a sizable Asian wheat market by 2030. Madhya Pradesh may focus on hard bread wheat that is demanded by the bakers, millers and the grain needs of the southern states.

Re-examine the variety release practice: Punjab has almost reached near attainable wheat yields and there are indications that there is no new varietal technology to bring in a 15 to 20 per cent quantum jump in productivity (Anonymous, 2012a). In the absence of such a production gain, Punjab farmer's income will be dependent on the annual MSP price increase declared by the Centre, which is often less than the annual rate of inflation. In other words, the purchasing power of the wheat growing farmer will get gradually eroded, and his real income may shrink. And unless new technological innovations are made to use the entire wheat biomass by the industry growing wheat merely for cereal needs will push the state and the farmer to hardship.

Since the International wheat improvement institutes focus on maximising grain yield and quality in a genetic background that is climate resilient (Rajaram and Braun, 2006; Dixon *et al.*, 2009), the national programmes also work on similar priorities (Anonymous 2012a). There is a felt need to integrate wheat research and wheat products technology on to a common platform. And unless the farmer and the industry is twined together; as in the case of sugarcane farmer and the multi-various sugar mill; wheat farmers may not be able to increase his total income by growing this as a cereal. As of now, wheat crop biomass is used as filler in cattle feed or pilferaged and wasted.

Wheat as morning breakfast cereal (BFC): Extruded breakfast cereal products such as corn flakes, rice flakes, wheat flakes and other formulated breakfast cereal product are now gaining popularity in India. Breakfast cereal is made by processing the grain of maize, rice, oats, wheat etc, and is often consumed with cups of cold milk, topped with nuts, resins etc. Breakfast cereals are produced by extrusion cooking method. For this purpose, single screw and twin screw extruders are available. Twin screw extrusion cooking method is used for producing high quality products with better texture and precise process control. Many companies are now providing turnkey plants based on twin screw extrusion technology. At present Kellogg's, Mohan Meakin and Baggery's are the major players. And the demand is rising for healthy food among the urban middle class. Due to high cardiac problems in India, caring for the heart is becoming more important and breakfast cereal producers, especially oat manufacturers, anticipate benefit from this trend. Cereals with other health or nutritional benefits, such as reduced sugar, high fibre or vitamin enriched will widen the choice for the consumer and fuel faster growth of the BFC market. Muesli is another breakfast cereal based on uncooked rolled oats, fruit, and nuts. Most firms focus on breakfast cereal where profits are > 45 per cent. The Indian breakfast cereal market is worth Rs 6000 million including Muesli that accounts for Rs 700 million. Multinationals dominate this segment and, Kellogg holds ~ 60-65 per cent of the Indian market share. Unless wheat research reshapes their research agenda for product development, native BFC companies will not be able to compete with the multinationals.

Wheat atta and other products: At present only 15 to 18 per cent of the total wheat produced in India is used by the roll flour mills. Of the remaining harvested wheat, less than 7 per cent goes as seed and for grain export. The remaining 76+ per cent is used by the village based unorganised stone roller grinding mills to produce whole grain *atta* that is used by millions of homes for baking flat Indian bread called "Chapati". Whole wheat flour has about 340 calories per 100 gm of weight and includes the mineral rich aleuron layer and vitamin rich germ (embryo). When wheat is ground without the aleuron layer and seed embryo the resultant white flour is "*maida*". Whole wheat is rich in "gluten" a protein conglomerate that increases the elasticity of the dough. From *maida*, pan bread, noodles, cakes, biscuit and pizza can be made. For every good quality product a specific and adapted wheat flour type is required.

Wheat Gluten is the natural complex protein derived from wheat or wheat flour. In its freshly extracted wet form, it is known as gum gluten which when dried yields a cream-to-tan-coloured, free-flowing powder of high protein content and bland taste. When re-hydrated, it regains its original characteristics. So unique is the functionality of wheat gluten and so persistent is the structural integrity

after cooking, it appears to have no functional competitor. Wheat gluten is prepared by removing starch from wheat flour by carefully drying the remaining high protein gluten to retain the native properties of the wheat gluten. Wheat gluten is used in bakery products, meats, pasta, breading and more. Gluten is water insoluble and separation from starch and other fractions is achieved by physical means from aqueous flour suspensions without additives of any kind. Gluten standards have been prescribed by the joint FAO/WHO Expert Committee on Food Additives and are also covered by Codex standards.

Wheat bran as food and feed: When wheat is roll-flour milled the aleuron layer that is removed becomes bran or wheat bran. It is rich in nutrition but cannot be stored for long like regular wheat flour as it has a tendency to rancid. Therefore, vacuum packing and storing bran at low temperature is recommended. A cup (58 g) of bran contains 99 per cent of the recommended daily allowance (RDA) of fibre, 9 g of protein and 34 per cent of the RDA iron. Bran is also rich in magnesium, manganese, niacin, phosphorus, zinc, vitamin B6 and low in fat, with no cholesterol, sugar or sodium. Bran has that uniqueness in providing a feeling of fullness as it absorbs water and expands in the digestive system. Adding bran to muffins is a natural choice and can be added to pancakes, biscuits, wafers, and cookies to enhance their nutritional value (Robin *et al.*, 2011). Developing micronutrient dense wheat varieties and recommending whole grain flour will mitigate some of the severe nutritional deficiencies. To discourage the supplementation of nutrients and vitamins to the flour, the Indian wheat breeding programme should recast their work-plan and focus on enriching the aleuron layer with iron and minerals and thus add value to the whole grain wheat flour.

Wheat starch: India produces about 0.38 million tons of starch from various crop sources and 50 per cent of the total starch need is from the food industry and the remaining goes for hydrolytic purposes. Tapioca, maize and sweet potato are the main sources of starch. Since wheat starch is unique and that there is surplus wheat in India, a part of it can be diverted for extraction of starch for use in food industry and by the degradable plastic industry. Wheat starch granules are of two types: large ovals of 15 – 45 μ m in diameter; and a smaller round granule of 2 – 7 μ m in diameter. This smaller type of starch is applied as a neutral dusting powder or as an ingredient in pharmaceutical preparations. There is paucity of information on the structure of starch granule in the Indian wheat and the purpose for which they can be used. The wheat grain quality data of the AICWIP should widen their information base and enable the growth of wheat starch industry in the country.

Starch based degradable plastic: Starch is a polymer and is a potential candidate for blending with plastic to render

it degradable; because it is cheap and the technology involved is easy to adopt. Plasticised starch could be used in injection moulding or thermoforming. Plasticised wheat starch and biodegradable polyesters allow the manufactured materials with greater water resistance. Such materials can be produced on industrial scale thermoforming to produce trays that can withstand 4°C to room temperature (Averous et al., 2001). Thermoformed article such as a food or beverage cup, lid, cutlery item, food service item, moulded tray, food storage container, etc provide the ability to resist deformation during higher temperature conditions during storage and distribution. The commercial formulation Cereplast Compostables® resins are renewable, 100 per cent ecologically sound substitutes for petroleum based plastic products. These resins are starch based, made from corn, wheat, tapioca, and potato. Resin manufacturing begins once the Cereplast production team selects the right biopolymer matrix made from renewable, cost - stable resources. The selected biopolymer is blended with other biodegradable components to reinforce its molecular structure through a proprietary process developed by Cereplast. The blend is then polymerized and treated with nano - composites for surface optimization and further reinforcement. The entire composite process is high speed and is low cost (Mitrus et al., 2009).

A good part of wheat exported by India probably is used by the importer as animal feed or is converted as bio-raw material for use by the manufacturing industry along the value chain. So far no serious effort has been made in India to develop wheat based technology to manufacture high value products. By re-orienting our wheat research program objectives and by involving the IITs / IIMs and venture capitalists from Punjab high-tech, eco-friendly thermoform products can be manufactured. By doing so, both the wheat farmer and emerging innovation based industries will get benefitted.

Wheat germ (WG) oil: Unrefined WG oil is dark in colour and also has a heavy smell. It is a good source of fatty acids that are very vital for the healthy growth of the human body. The germ forms only 3 per cent of the weight of a wheat grain but, nonetheless, contains about 25 per cent of the protein, vitamins and minerals and so wheat germ oil has numerous nutritional benefits.

India produces more than 93.0 million tons of wheat annually and of this may be more than 10 mt goes for roll-flour mills. And during the process of milling the aleuron layer and embryo or the germ gets removed. This by-product is invariably used as animal feed. By using the separated germ / embryo the millers can produce 20,000 metric tons of WG oil. Wheat germ contains 8-14 per cent oil and the crude oil is generally high in unsaponifiable matters (2-6%) and with high content of tocopherols (Vitamin E). One kilo of WG oil contains

about 1179 mg a-tocopherols, 398 mg b-tocopherols, 493 mg g-tocopherols and 118 mg d-tocopherols (Tong and Lawrence, 2001). Vitamin E constitutes an integral part of phospholipids found in cell membrane and preserves the integrity of all cells especially free cells with short life span e.g. red white blood cells and blood platelets. Also, vitamin E inhibits the oxidative interaction of LDL(s) (Low Density Lipids) and prevents their deposition on the arterial walls. Tocopherols contain a considerable percentage of poly-unsaturated fatty acids. The linoleic acid content ranges between 44 to 65 per cent and the linolenic acid content ranges between 4 to 10 per cent. Minerals like phosphorus, iron, zinc, potassium and sulphur present in the oil provides the essential nutrients to skin nourishment. The WG oil is very good for human health and wellness. Several health care products can be commercialised having WE as the basis. In that process value addition to wheat will also happen.

Wheat straw cellulose and paper industry: The fundamental properties of pulp fiber are length, diameter/width, and cell wall thickness lumen diameter/width. Indian pulp and paper statistics reveal that the industry uses 39 per cent of forest based fiber, 31 per cent agro-residue based fiber and 30 per cent fiber recycled from waste paper. The Indian paper industry produces two types of fresh pulps ie. Chemical pulps through either soda process or kraft process, and the chemi-mechanical pulps. Each material has distinct morphological characteristics of pulp fiber and chemical composition that regulate the quality of paper products during manufacturing (Anonymous, 2004).

The small and medium size paper mills in India make writing and printing paper from wheat straw. On an average the Harvest Index (ratio between total above ground biomass: grain) in wheat is 0.4 (Zhang et al., 2012) which means that 60 per cent of the above ground biomass is straw from stem, leaf and spike. Cellulose samples with molecular weights ranging from 8.39×10^4 to 11.00×10^4 g/mol are obtained from wheat straw. The de-waxed wheat straw pre-treated with aqueous hydrochloric acid followed by delignification is an eco-friendly benign poly (ethyleneglycol) / salt aqueous biphasic system. This yields cellulose 48.9 –55.5 per cent along with 1.2 –3.2 per cent hemicelluloses and 0.97 – 3.47 per cent lignin (Yan et al., 2012).

During crop year 2012, India harvested more than 93.0 mt of wheat grain and must have produced another 130 mt of straw. Of the total available wheat straw may be 1 to 2 per cent which is being used by the paper industry. Trident, a modern integrated pulp and paper plant commissioned in Punjab has emerged as the largest wheat-straw based paper plant in the world and one of the largest yarn producers in India. There is considerable opportunity for the growth of the wheat straw based paper industry. The wheat research programme and the paper technology may have to come closer to evolve how best the wheat straw can be used

avoiding the field burning and burying of this renewable resource. In doing so, forest cover can increase as trees will be spared and a pro-climate industrial growth can be triggered.

Wheat biomass and ethanol production: The cellulose in biomass can be hydrolyzed to sugars that can be fermented to form ethanol, as around 34% of the wheat straw accounts for cellulose. And the spiraling petro products price has made the future of the bio-based products and fuels very bright. Research has shown the potential use of wheat straw cellulose derived nano-fibers as substitute for fiberglass, plastics and in many automotive parts. Economics of producing cellulose nano-whiskers (CNW) as a co-product in an ethanol bio-refinery has been worked-out in North Dakota, USA. And now technologies are there for commercialization that would allow wheat straw to get processed in a bio-refinery to produce ethanol, cellulose nano-fibers and high value chemicals as succinic acid, butanetriol, and xylitol. The bio-refinery concept is economically attractive because it offers a potential to capture greater value from the biomass feedstock (Leistriz *et al.*, 2006).

Malting wheat and for leisure times: Malted wheat is slightly sweet in taste and is to be used for up to 50 per cent of a grain bill, and typically needs to be mashed to help in lautering and prevent stuck mashes. Wheat malt can make for a sticky mash that is hard to lauter, and promotes a very slow run off. The LOX (Lipoxygenase) in wheat have been investigated due to the influence

it has on the sensory quality of wheat products. The LOX activity among the cultivated diploid (einkorn, *T. monococcum*), tetraploid (durum wheat, *T. turgidum* subsp. durum) and hexaploid (bread wheat, *T. aestivum*) indicates the highest enzymatic activity in *T. aestivum*, followed by *T. turgidum* and *T. monococcum* at a pH range of 5–6. The LOX activity was higher in the germ than in the bran or in the endosperm. Despite all this, wheat malt is widely used in China's beer industry. Sensory deterioration of beer during distribution and consumption is one of the most serious problems of what malt based beer. Selecting the appropriate wheat variety and improving the malting process may contribute to a lower LOX activity. Raising the mashing temperature could reduce the LOX activity in the mash, and further decrease the potential for off-flavour substances. In addition, reducing the LOX activity could also shorten the filter time, decrease the wort turbidity, and improve the quality of the malt. In summary, decreasing the LOX activity in wheat malt could help to improve the quality of beer (Sun *et al.*, 2012). Experiments were conducted during two seasons (2008 and 2009) with bread wheat variety Adriana that has poor values for α -amylase activity and diastatic power. Micromalting procedure (green malt) and quality indicators, namely, fine and coarse extract, total and soluble proteins, Kolbach index, viscosity, saccharification time, lautering time, and Hortong number of Adriana showed that this bread wheat variety has good malting and beer properties (Krstanovic *et al.*, 2009).

Table 1. Evolution of the wheat improvement activities in India and needs of 2030

Period	Varieties	Major Features
1920 -1930 till 1962	NP 4, NP 12, etc NP 200, NP 800 series,	Mass selection, better yielding, bold lustrous grain Cross between tall, good chapati quality grain, rust susceptible
1962 -1969	C 591, K 68, PKD 4, PV 18, C 306, Lerma Rojo, Sonalika, Sonora 64, Sharbati Sonora, Kalyansona	Mexican dwarf, CIMMYT, germplasm used, rust resistant, varying maturity
1970s	HUW 12, Hira, Hyb 65, Moti, WL 711, WG 357, WH 147, HD 2009, HD 2189	CIMMYT genotypes used for breeding varieties in India, rust resistant, Karnal Bunt tolerant
1980s	GW 1, Kundan, Raj 1555, HD 2329, HI 977, HUW 234	Mainly Indian effort, CIMMYT germplasm widely used
1990s	PBW 343, UP 2338, WH 542	Indian crosses with CIMMYT's Kauz, Atila, Seri, Veery etc. 1B/1R dominates and baking quality suffers
2000s	DBW 14, DBW 17, PBW 590, DPW 621-50, HD 2967, PBW 550	Novel traits, yellow rust resistance gains importance
2030s	Super wheat	Hybrids, biomass valued, processing quality shall gain focus. Technological break through to happen

Building wheat based high-tech industry: In India, wheat breeding approach and priorities have been constantly evolving in response to the social needs (Table 1) and to ensure that wheat growing farmers have an economic wellbeing. The demand from the industry by 2030 from wheat farmers is going to be of altogether different kind.

Wheat will gradually move as an industrial crop for an end to end usage. Plant breeders should take note of this and re-galvanize breeding and selection strategies. In turn the DWR and ICAR has to evolve a more pragmatic variety testing and evaluation, moving away from yield driven programme to biomass utilization programme.

In fact the wheat varieties for the NWPZ should be developed with as many industrial traits as possible and shift the emphasis from grain to industrial use of the crop biomass. The total biomass of wheat should be used for the manufacturing of various products explained earlier and the plant breeder's selection criteria, design of the crossing block, selection, generation advancement and evaluation procedures must undergo a change. Accordingly, new germplasm would be required, a new cadre of personnel are to be trained in emerging industrial bio processing, and state of art equipment must be acquired. In short, the business as usual approach to wheat improvement, the routine AICRIP trials, ritualistic solemnizing the ongoing research should be replaced by a carefully thought and planned new initiative so that by 2030 wheat bio processing industry can come in Punjab and other states.

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