WHOLE GRAINS FOR HEALTH

Production, Consumption, Utilization & Health Benifits

International Life Sciences Institute-India

India & South Asian Region

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- toxicology and risk science
- nutrition, health and well-being
- sustainable agriculture and nutrition security

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Preface

Over the years there have been significant changes in food basket in India partly because of improvement in economic status of people. Even now the bulk consumption is grains but the kind of grains that are primarily consumed and the form in which they are consumed are different. This change has not been for reasons of health but more for taste and convenience.

More specifically, two basic changes can be identified. First the proportion of whole grains consumed has dropped substantially in favor of processed grains. Processing eliminates essential ingredients and causes severe loss of nutrients. Surely, from the initial whole grain to final consumer product there is addition in value in terms of money but a huge loss in terms of nutrition. While some minimum processing is required to make grain consumable, processing should replace all the components in the grains including fiber, vitamins and minerals, carbohydrates and proteins, healthy fats and antioxidants.

Second the grains in the diet now consist mainly of rice and wheat. The consumption of what have been called coarse grains like jowar, barley, ragi has declined. This is unfortunate because coarse grains are richer in nutrition. Besides they are really dry land crops and can sustain production in climate change.

The increased incidence of NCDs has made consumer aware of the adverse effects of change in grain consumption and loss of nutrients in processing. Some change in diet is now discernible in urban areas though in villages consumption of whole grains is not uncommon. With the increased demand for coarse grains food companies also have been producing multigrain products with health benefits. Nevertheless greater awareness on the part of the consumer can make a difference to diet and health.

This monograph on "Whole Grains for Health", it is hoped will create consumer awareness and bring about the desirable change in diets for better health.

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Chairman, ILSI-India

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The Conference was addressed by: Mr. D H Pai Panandiker, (*Chairman, ILSI-India, New Delhi; Mr. N M Kejriwal, President, ILSI-India, New Delhi*); Dr. Sudha Vasudevan, (*Sr. Scientist and Head, Department of Foods, Nutrition and Dietetics Research (FNDR) Madras Diabetes Research Foundation, Chennai*); Dr. T Longvah, (*Director -In charge, National Institute of Nutrition, Hyderabad*); Dr Yi Fang Chu, (*R&D Director, PepsiCo R&D Nutrition, USA*); Dr S Shobana, (*Scientist, Department of Foods Nutrition and Dietetics Research, Madras Diabetes Research Foundation, Chennai*); Ms. Rekha Sharma, (*President and Director, Nutrition and Dietetics, Diabetes Foundation (India), New Delhi*); Dr. P. Saxena, (*Additional DDG, Nutrition & IDD Cell, DGHS, Ministry of Health and Family Welfare, GOI, New Delhi*); Dr. A S Bawa, (*Former Director, Defence Food Research Laboratory, Bengaluru*); Dr. Kamala Krishnaswamy, (*Former Director, National Institute of Nutrition & Emeritus Medical Scientist (ICMR), Hyderabad*); Dr Srinivas. A, (*Senior Principal Scientist and Head of the Department of Grain Science and Technology, CSIR - Central Food Technological Research Institute, Mysuru*); Dr. Sagar Kurade, (*Managing Director, Suman Project Consultants (P) Ltd., New Delhi*); Dr. K. Madhvan Nair, (*Scientist F, Micronutrient Research, NIN (retd.), Hyderabad*); Dr. Ravindra Kumar, (*Quality and Food Safety Lead – AP, DuPont, Nutrition and Health, Gurgaon*); Dr. Rakesh Kumar Sharma, (*Director, Defence Food Research Laboratory, Mysuru*); Dr. Shilpa Joshi, (*Hon Secretary, All India Association for Advancing Research in Obesity, Mumbai*); Dr Santosh Jain Passi, (*PHN Expert & Former Director, Institute of Home Economics, University of Delhi, New Delhi*); Mr. Devender Kumar, (*Vice President, F & B, Hotel Le Meridien, New Delhi*); and Ms. Ankita Marwaha,(*Associate Director-Nutrition Sciences, PepsiCo India Holdings Pvt. Ltd., Gurgaon).*

This Monograph has been drafted by Dr. Pulkit Mathur, *Assistant Professor, Dept. of Food and Nutrition, Lady Irwin College* in consultation with Mr. D H Pai Panandiker, *Chairman, ILSI-India* and Ms. Rekha Sinha, *Executive Director of ILSI-India*.

The Monograph includes essence of the presentation and discussions at the conference and further inputs and observations by Dr. Pulkit Mathur. ILSI-India acknowledges her contributions.

Whole Grains For Health

HIGHLIGHTS

- Whole grains consist of the entire cereal grain seed/kernel - bran, endosperm and germ. A food product providing substantial amounts of whole grain must contain at least 8 g of whole grains/30-g serving of food.
- There is strong evidence that whole grain consumption has been associated with several health benefits which include a decrease in risk of cardiovascular diseases (CVD), Type 2 diabetes (T2DM) and cancer. Their consumption also helps in weight management and improves gastrointestinal health.
- Whole grains are a good source of nutrients like protein, complex carbohydrates, fibre, essential fatty acids, minerals (like iron, calcium, magnesium, selenium, zinc, etc.), vitamins (like thiamine, riboflavin, niacin, folic acid, etc.) and phytochemicals which have health benefits.
- Eating a variety and replacing half of the grains consumed daily with whole grains has been recommended by many international dietary guidelines.
- Processing especially refining and polishing of grains reduces the nutritive value and the healthfulness of whole grains. Grinding increases the glycemic index of whole grains. Hence it is recommended to consume, as far as possible, intact whole grains.
- As this is not always possible, there is a need for developing products made from whole grains which have been processed in a way to retain the nutrients and phytochemicals.
- Processing technology, which increases shelf life of whole grains and their products as well as reduces glycemic index is needed.
- Food fortification and enrichment with value-added ingredients can improve the nutritional quality of whole grain products. Bioavailability of the added nutrients needs to be considered.
- Several strategies are needed to encourage whole grain consumption among consumers like educating consumers of all ages about the health benefits and making tasteful whole grain preparations which are appealing to both adults and children.

Section 1
What Are Whole Grains?

1.1: Background

Whole grains became a part of human diet with the advent of agriculture about 10,000 years ago and got allied with society and culture.

Whole grains consist of the entire cereal grain seed or kernel. The kernel in turn consists of three parts – bran, endosperm and germ (figure 1). Examples of whole grains include whole wheat, brown rice, coloured rice, rye, oats, maize, barley, sorghum/jowar, triticale, millets - bajra (pearl millet), ragi (finger millet), etc. and peudocereals like quinoa, buckwheat, amaranth and wild rice.

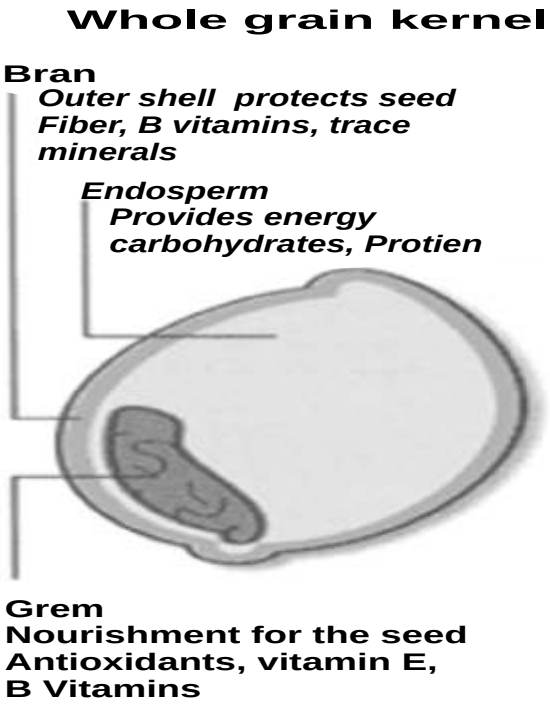

Figure 1: Structure and Composition of a Whole Grain Kernel

Source: https://commons.wikimedia.org/wiki/File:Grain.gif

1.2: Definition

Whole grains have been defined by different organisations as -

"Intact, ground, cracked or flaked fruit of the grain whose principal components, the starchy endosperm, germ and bran, are present in the same relative proportions as they exist in the intact grain"- the American Association of Cereal Chemists International (AACCI)

This definition has been adopted and used by the Food and Drug Administration of the United States.

"*Whole grains or foods made from them contain all the essential parts and naturally-occurring nutrients of the entire grain seed in their original proportions. If the grain has been processed* (e.g., cracked, crushed, rolled, extruded, and/or cooked), *the food product should deliver the same rich balance of nutrients that are found in the original grain seed*"- Whole Grain Council (2004)

"Whole grains consist of the intact, ground, cracked or flaked kernel after the removal of inedible parts such as the hull and husk. The principle anatomical components—the endosperm, germ and bran—are to be present in the same relative proportions as they exist in the intact kernel. Small losses of components, i.e., <2% of the germ or <10% of the bran, which may occur through processing methods consistent with safety and quality, are allowed" - The European HEALTHGRAIN Forum, a European Union consortium

This definition is like those given by other bodies but is distinct in the fact that it also provides for small losses which may occur during initial cleaning and processing of grain.

1.3: Nutrient Content

The three components of a cereal grain– the bran, endosperm and the germ have a different nutritional composition. The outer bran layer is rich in nutrients like fibre, B vitamins, minerals and phytochemicals. The endosperm is the major chunk of the grain and is primarily made up of carbohydrates and protein. The germ portion of the grain is again rich in essential fatty acids, minerals, B vitamins and antioxidants like vitamin E. Besides macro and micronutrients whole grains are endowed with bioactive substances such as phytochemicals (phenolic acids, polyphenols, phytates, alkyl resorcinol, phytosterols) and dietary fibers which may work synergistically to contribute to the observed whole grain health benefits. Figure 2 shows the nutrients likely to be present in whole grains.

Once processed, whole grains lose much of their fibre and important beneficial nutrients like vitamins, minerals, essential fatty acids,

and bioactive components. This is because during processing the bran and germ may be lost resulting in only the starchy endosperm being used to make what are referred to as 'refined' grain products. Processing is a prerequisite of using grains as food and with technological knowhow and consumer preference refined grain/flour use has increased rapidly.

The rapidly changing food system and sedentary lifestyle have contributed substantially to the surge in prevalence of non-communicable diseases. Appreciation of the health benefits of whole grains has led to a renewed interest in the consumer regarding products made from whole grains including the coarse grains. Several epidemiological studies have found that diets rich in whole grains protect against cardiovascular disease, stroke, type 2 diabetes, and certain cancers. The protective effects of whole grains may depend on the presence of several biologically active constituents, including dietary fibre, vitamin E, magnesium, folate, and other micronutrients. The beneficial effect is also mediated through food structure, and its relation to absorption of nutrients and glycemic control.

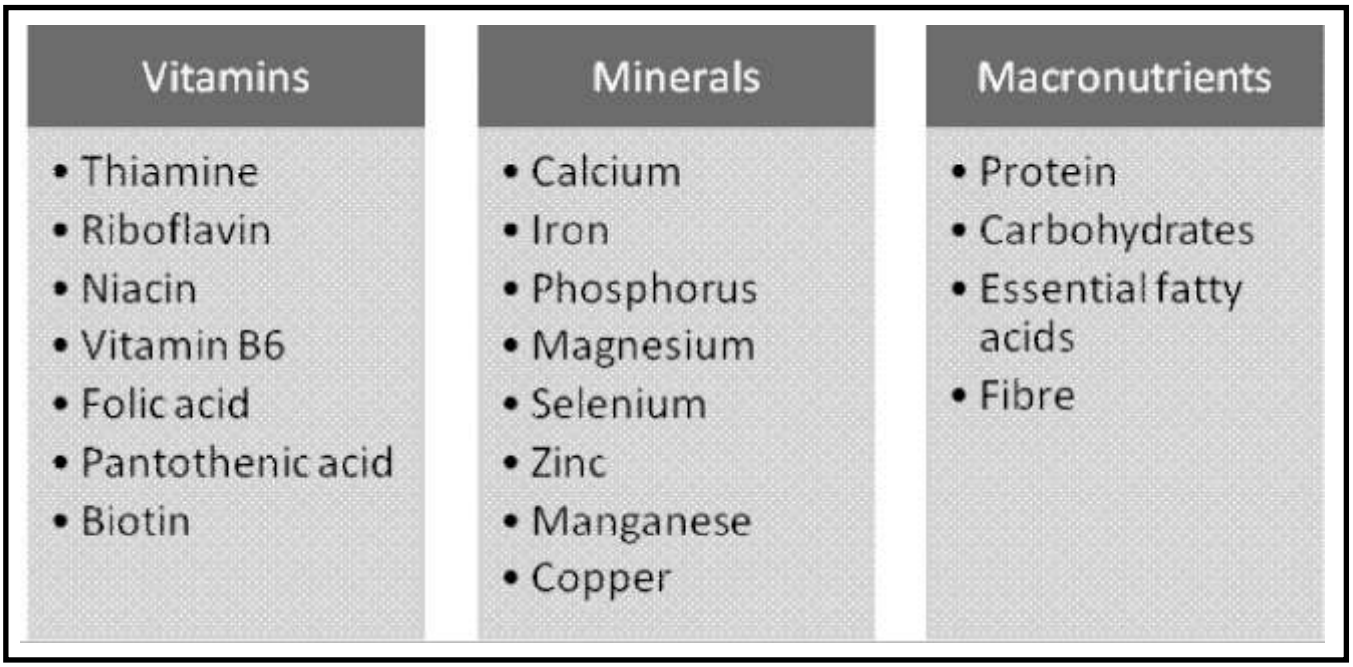

Figure 2: Nutrients Present in Whole Grains

Nutritive value changes with the different types of grains. Some grains have higher amounts of some nutrients while others are rich in some other vital nutrients or phytochemicals. Tables 1a and 1b give the nutritive value of commonly consumed cereals and millets in India, though it is not clear whether whole intact grains were used for the estimation in the referred database.

Table 1a: Macronutrient and Mineral Content of Commonly Consumed Cereal Grains and Millets of India (per 100g edible portion)

Cereal/Millet	Energy (KJ)	Carbohydrate (g)	Protein (g)	Fat (g)	Total Dietary Fibre (g)	Soluble Dietary Fibre (g)	Calcium (mg)	Iron (mg)	Zinc (mg	Magnesium (mg)	Copper (mg)
Wheat whole	1347	64.72	10.59	1.47	11.23	1.60	39.36	3.97	2.85	125	0.49
Whole wheat flour (atta)	1340	64.17	10.57	1.53	11.36	1.63	30.94	4.10	2.85	125	0.48
Refined wheat flour (maida)	1472	74.27	10.36	0.76	2.76	0.62	20.40	1.77	0.88	30.69	0.17
Brown rice	1480	74.80	9.16	1.24	4.43	0.82	10.93	1.02	1.68	93.91	0.37
Milled white rice	1491	78.24	7.94	0.52	2.81	0.82	7.49	0.65	1.21	19.30	0.23
Milled, parboiled rice	1471	77.16	7.81	0.55	3.74	0.76	8.11	0.72	1.08	26.72	0.27
Maize	1398	64.77	8.80	3.77	12.24	0.94	8.91	2.49	2.27	145	0.45
Oats*	1629	67.50	16.89	6.90	10.60	-	54.00	4.72	3.97	177	0.63
Sorghum/jowar	1398	67.68	9.97	1.73	10.22	1.73	27.60	3.95	1.96	133	0.45
Barley	1321	61.29	10.94	1.30	15.64	5.66	28.64	1.56	1.50	48.97	0.43
Bajra	1456	61.78	10.96	5.43	11.49	2.34	27.35	6.42	2.76	124	0.54
Ragi	1342	66.82	7.16	1.92	11.18	1.67	364	4.62	2.53	146	0.67
Quinoa	1374	53.65	13.11	5.50	14.66	4.46	198	7.51	3.31	119	0.48

Source: IFCT, 2017

*USDA Food Composition Database https://ndb.nal.usda.gov/ndb/foods/show/6507?manu=&fgcd=&ds=

Table 1b: Vitamin Content of Commonly Consumed Cereal Grains and Millets of India (per 100g edible portion)

Cereal/Millet	Beta-Carotene (µg)	Vitamin E (mg)	Thiamine (mg)	Riboflavin (mg)	Niacin (mg)	Pantothenic acid (mg)	Vitamin B6 (mg)	Biotin (µg)	Total Folates (µg)
Wheat whole	3.03	0.77	0.46	0.15	2.68	1.08	0.26	1.03	30.09
Whole wheat flour (atta)	2.67	0.26	0.42	0.15	2.37	0.87	0.25	0.76	29.22
Refined wheat flour (maida)	1.97	0.05	0.15	0.06	0.77	0.72	0.08	0.58	16.25
Brown rice	-	0.69	0.27	0.06	3.40	0.61	0.37	1.38	11.51
Milled white rice	-	0.06	0.05	0.05	1.69	0.57	0.12	0.60	9.32
Milled, parboiled rice	-	0.09	0.17	0.06	2.51	0.55	0.22	0.31	9.75
Maize dry	186	0.36	0.33	0.09	2.69	0.34	0.34	0.49	25.81
Oats*	0	-	0.76	0.14	0.96	1.35	0.12	-	56.00
Sorghum/jowar	8.29	0.06	0.35	0.14	2.10	0.27	0.28	0.70	39.42
Barley	-	0.01	0.36	0.18	2.84	0.14	0.31	2.38	31.58
Bajra	28.23	0.24	0.25	0.20	0.86	0.50	0.27	0.64	36.11
Ragi	1.53	0.16	0.37	0.17	1.34	0.29	0.05	0.88	34.66
Quinoa	5.12	2.08	0.83	0.22	1.70	0.62	0.21	0.62	173

Source: IFCT, 2017

*USDA Food Composition Database https://ndb.nal.usda.gov/ndb/foods/show/6507?manu=&fgcd=&ds=

Section 2
Whole Grains & Health Benefits

2.1: Health Benefits-Overview

Whole grains have been associated with several health benefits. The group of people with the highest intake of whole grains had a 17% lower risk of mortality from all-causes and 11–48% lower risk of specific-cause mortality (Huang et al, 2015).The different constituents of whole grains contribute to the beneficial physiological effects seen. A synergistic effect of different constituents may also be responsible for the health benefits seen. For instance, dietary fibre has been shown to improve intestinal function and glucose and lipid metabolism. Lignans are phytoestrogens, polyphenols and phytates are antioxidants, tocopherols and trienols are antioxidants, reducing low density lipoprotein (LDL) oxidation, oligosaccharides are prebiotics, alkylresorcinol are enzyme inhibitors, phytosterol has cholesterol lowering effect, folate, choline and betaine are methyl donors, while magnesium and chromium improve insulin sensitivity.

Epidemiological studies and dose-response meta-analysis of prospective studies on health benefits of whole grain consumptionhave shown a reduced risk of the following:

- Cardiovascular diseases (CVD)
- Type 2 diabetes mellitus (T2DM)
- Colorectal cancer
- Cancer
- Infectious diseases
- Mortality from all causes

Other Health benefits seen:

- Blood pressure lowering
- Weight management
- Gut health

Source: (Lutsey et al, 2007; Masters et al, 2010; Gaskins et al, 2010; Katcher et al, 2008; Qi et al, 2006; Ye et al, 2012; Aune et al 2011; Aune et al, 2016).

Weight Management

Fibre, a component of whole grains, is an important part of our diet. Both insoluble and soluble fibre gives us satiety, which helps in weight management and prevents obesity. Diets rich in complex carbohydrates are healthier than low-fibre diets based on refined and processed foods. A study showed that for every 40 g/day increment in whole grain intake from all foods, weight gain was reduced by 0.49 kg during 8 years of follow-up (Koh-Banerjee et al, 2004). The potential mechanisms which regulate body weight are perhaps a decreased dietary energy density, increased satiety, slower gastric emptying, slower digestion and

absorption, reduced postprandial glycemic response and modulation of the gut microbiota.emic response and modulation of the gut microbiota.

Cardiovascular Diseases

Diets rich in whole grains reduce the risk of coronary heart disease, by lowering the LDL cholesterol and triggering a protective effect against clogged arteries by preventing the formation of blood clots. Large epidemiological studies on a variety of different populations note that people who eat three daily servings of whole grains have been shown to reduce their risk of heart disease and stroke. There was a 21% reduction in CVD risk for those who were in the highest category of whole grain intake versus the lowest (Ye et al 2012).

Type 2 Diabetes

A study on Type 2 Diabetes respondents showed that consumption of two servings per day of whole grains was associated with a 21% risk reduction for T2 DM (deMunter, 2007). Other studies have shown similar results. In intervention studies where whole grains became a regular part of the diet, people showed improved blood glucose levels and insulin sensitivity.

Gut Health

The impact of whole grain wheat and wheat bran on the gut microbiota was compared in a double-blind, randomised, crossover study on thirty-one volunteers (Costabile et al., 2008). Daily consumption of whole grain wheat was found to exert a pronounced prebiotic effect on the human gut microbiota composition as compared to wheat bran.

Around 45 studies (64 publications) were included in a meta-analysisto quantify the dose-response relation, between consumption of whole grain and the risk of cardiovascular disease, total cancer, and all cause and cause specific mortality. (Aune et al, 2016). The review pointed out that whole grains being rich in fibre, can reduce the postprandial glucose and insulin responses leading to better glycemic control. A lower risk of overweight and obesity and of type 2 diabetes among people with a high whole grain intake was suggested by the review. Though both adiposity and type 2 diabetes are established risk factors for cardiovascular disease, cancer, and mortality, in this analysis all the studies adjusted for body mass index (BMI), suggested an association independent of BMI. The relative risks per 90 g/day increase in whole grain intake was 0.81 for coronary heart disease, 0.88 for stroke, and 0.78 for cardiovascular disease, with similar results when studies were stratified by whether the outcome was incidence or mortality. Reductions in risk were observed up to an intake of 210-225 g/day for most of the outcomes. Intakes of specific types of whole grains including whole grain bread, whole grain breakfast cereals, and added bran, as well as total bread and total breakfast cereals were also associated with reduced risks of cardiovascular disease and/or all- cause mortality, but there was little evidence of an association with refined grains, white rice, total rice, or total grains.

2.2: Health Benefits of Select Whole Grains

Wheat and Brown Rice

Wheat and rice are the most widely consumed food grains in India. The health benefits of wheat depend entirely on the form in which it is eaten. Wheat is shown to reduce chronic inflammation because of the betaine content. Whole wheat provides additional vitamins like Vitamin B, Vitamin E, minerals and fibre that can assist in weight loss. The fibre found in whole grain wheat improves satiety resulting in less intake of calories. It lowers the risk of heart diseases as it has omega 3 fatty acids.Wheat is rich in magnesium which is a mineral that acts as a co-factor for more than 300 enzymes. These enzymes are involved in the body's functional use of glucose and insulin secretion.

Milling reduces the nutritive value of the grain as the bran layer and germ portion are usually removed from the grain during the process. In both rice and wheat, it has been seen that all nutrients except carbohydrates, like - protein, total dietary fibre, minerals, total fat and phytates decrease on refining the grain. The loss can be as high as 75% of the total dietary fibre in wheat, 50% of the fat, 60% of the minerals and 80% of the phytate.

In rice the loss of total dietary fibre can be as high as 36%, 13% of protein, 46% minerals, 58% total fat and 64% phytates. Although phytic acid reduces bio availability of some minerals (like calcium, iron and zinc) and their decreased levels in refined grains may actually increase absorption, however refined grains have lower levels of these minerals to start with. Further, phytates are now considered as bioactive compounds which have been associated with cancer prevention as they are antioxidants. Several other protective phytochemicals like oryzanol (in rice), β sitosterol, stigmasterol, total polyphenolic compounds, and campesterol decrease in wheat on refining. Thus, the contribution of grains to the intake of different nutrients and phytochemicals decreases.

It has also been seen that 100g of whole wheat flour contributes to about 37% of the RDA for magnesium while refined wheat flour contributes only 9%. Similarly, 100g whole wheat contributes 35% of the RDA for thiamine while a similar amount of refined wheat flour would contribute to only 12.5%.

Hand pounded rice has higher nutrient content as compared to milled, polished rice. In fact, the consumption of polished rice as a major component of the diet has been linked to Beriberi, the disease caused by deficiency of thiamine. High fibre variety of white rice has been developed in India with a lower glycemic index than the normal white rice available. This variety also has a higher amount of resistant starch and amylose content (Mohan et al, 2016).

Colour of whole grain rice can be brown, red, purple or black depending on the presence of different phyto chemicals. Historically brown rice was consumed by people with ailments with possibly the health benefits being mediated through its phyto chemical components. Brown rice contains similar types of compounds like other whole grains

and in addition it also contains γ-oryzanol, vitamin D2 and tocotrienols. Whole grain black rice is now considered a functional food due to the high levels of phenolic compounds especially anthocyanins.

Germination of brown rice improves cooking quality and nutritionalvalue and organoleptic qualities. Significant increases in bioactive compounds such as γ-aminobutyric acid(GABA), dietary fibre, inositols, ferulic acid, phytic acid, tocotrienols, magnesium, potassium, zinc, γ-oryzanol have been reported. Germination also activates the production of phytase, which catalyses phytate breakdown, thereby making the divalent minerals more bioavailable. Total phenolics increased to a maximum level after a germination time of 24hours while gamma amino butyric acid (GABA), which was not present before germination, developed insignificant quantities upon germination. Novel acylatedsteryl glucosides found in soybean has also been reported to be present in germinated brown rice.

Germinated brown rice is now being marketed in southeast Asia as "GABA rice"(Patil and Khan, 2011).

The glycemic index of wheat maybe lower than white rice, but glycemic load of products like *phulkas* is more than that of white rice. This is probably due to the fact that *phulkas* have a lesser moisture content as compared to rice. Whole grain products can have a high glycemic load.

Whole grains have a higher fibre content which can affect the bioavailability of minerals like iron, calcium and zinc. Studies have shown that in anaemic women subjects, iron absorption was better in the wheat based diet group (11.2%), as compared to rice (8.3%) and millet (4.6%) based diets (Kalasuramath et al 2013). Millet based meals have the lowest bioavailability, while the rice and wheat based meals had moderate to good bioavailability. In millet based meals, it is prudent to consider ways to improve iron absorption.

Grain Legumes

Although whole grain definitions do not include grain legumes, they have similar nutritional benefits and can actually improve protein quality when consumed along with cereals. Grain legumes can be consumed as whole grains or after removing hull and splitting the grain as *dal*. However, removal of the hull decreases the dietary fibre, phytate, B vitamins and mineral content of the legume. The fat, protein and available carbohydrates increase. There is a significant decrease in total polyphenol content but an increase in oligosaccharides like raffinose and stachyose. So 100g of whole grain legume like red gram would provide 114% of the RDA for folate while the *dal* would provide only 54%. Similarly, thiamine's contribution would nearly halve if whole grain legume was dehulled and split into *dal*.

The mineral content of legumes is generally high, but the bioavailability is poor due to the presence of phytate - the main inhibitor of iron and zinc absorption. Some legumes also contain considerable amounts of iron-binding polyphenols inhibiting iron absorption.

Furthermore, soya protein per se has an inhibiting effect on iron absorption.

Efficient removal of phytate, and probably also polyphenols, can be obtained by enzymatic degradation during food processing, either by increasing the activity of the naturally occurring plant phytases and polyphenol degrading enzymes, or by addition of enzyme preparations. Biological food processing techniques that increase the activity of the native enzymes are soaking, germination, hydrothermal treatment and fermentation.

Oats

Oats have been used for hundreds of years andtheir use, documented in the Compendium of Materia Medicaof China,dates back to 1578 AD. Documentation available in ancient texts show that oats have been used as an anti-inflammatory product especially in some skin conditions,In addition to the nutrients contained in most whole grain cereals, oats have in their bran layer a soluble fibre called β-glucan.Oats contain the highest amount of protein and lipid among all commonly eaten grains like wheat, maize and rice. Further, protein digestibility corrected amino acid score (PDCAAS) value is higher than that of wheat or rice, indicating better protein quality.The amount of dietary fibre is similar to whole wheat flour but higher than that in whole grain corn meal (7%) and brown rice (4%). Oats contain good fats like MUFA in proportions higher than most other cereals. B vitamins and minerals are also present in higher amounts.

The research evidence on oats role in reducing blood cholesterol and in promoting satiety is very solid. The evidence is still growing regarding role played by oats in glucose metabolism. β- glucan found in oats may slow down glucose absorption after a meal. More research is needed on effect of eating other foods along with oats on the blood glucose levels. Oats contain a unique antioxidant called avenanthramide. Its ability to reduce oxidative stress in the body is a promising area of research. There is also preliminary evidence of the prebiotic fibre in oats maintaining gut as well as overall health.Two servings per day of whole grain has been associated with a 21% risk reduction for T2DM (de Munter et al, 2007).

A considerable amount of research has been published on the health effects of oats. This has been particularly true for cardiovascular risk factors and indices of carbohydrate metabolism (e.g., glucose/insulin levels).Work in nascent areas such as post-prandial glycemic responses, antioxidant and anti-inflammation have also been noteworthy. Furthermore, the relationship between the physical characteristics of oats (e.g., viscosity, molecular weight) and health effects has been explored in greater detail.

As regards cardiovascular risks, consumption of 3-6 g/d oat β-glucan significantly lowers the risks by reducing atherogenic elements of the lipoprotein profile such as low-density lipoprotein cholesterol (LDL-C), non-high-density lipoprotein cholesterol (non-HDL-C), small dense LDL, LDL particle number, and apolipoprotein B (Pomeroy et al, 2001; Davy et al., 2002; Saltzman et al., 2001; Berg et al., 2003). Oat consumption has also been associated with increases in HDL-C in studies on hyper-triglyceridemic individuals. Data are

inconsistent on the effects of oats and oat components on blood pressure, with some indication of a modest hypotensive effect in obese subjects and individuals with treated hypertension (Maki, et al.,2007; Keenan et al. 2002;Pins et al.2002).

Data concerning the impact and magnitude of oat and β-glucan consumption on modulation of glucose homeostasis are conclusive. Several well-controlled clinical trials suggest a dose-related, beneficial effect, especially when oat products (in contrast to β-glucan) are consumed and postprandial responses (in contrast to fasting values) are assessed (Alminger and Eklund-Jonsson, 2008; Behall et al., 2005; Hatonen et al., 2006). Data is conclusive on oat's effect in improving satiety and giving a feeling of fullness (Rebello et al., 2013; Geliebter et al., 2015; Rebello et al. 2014).

Studies also provide mixed results concerning the potential long-term effect of consumption of oats or its constituents on modulating weight gain in adults (Maki et al., 2010). Several in vitro studies have shown that oats can favourably affect gut microbial metabolism in ways that might potentially benefit gut and whole-body health, although studies on laxation have not yielded positive results. It is possible that physiochemical characteristics of oats affect fermentability.

There are small yet increasing numbers of well-designed clinical studies in the area of oats and the potential for oats to serve as dietary anti-oxidative and/or anti-inflammatory substances (Koenig et al., 2015; Koenig et al., 2014; Chen et al., 2007). Emerging in vitro data suggest plausible and potential physiologically relevant effects. Finally, there seems to be a growing appreciation for the relationship between the physio-chemical properties of oats and oat fractions and health-related variables, particularly for emerging areas such as glycemic response management and antioxidant potential. Positive outcomes may be dependent on oat processing, variety selection, and preparation before consumption. Effect of these variables needs to be better characterized.

It can be ensured that there is slow release of glucose from whole grains if appropriate technology is used for processing. Addition of certain ingredients like fibre, starch, sugar, the order of adding the different ingredients, using a low moisture dough, low baking temperature and short baking time can also reduce the release of glucose. By controlling the moisture, the gelatinisation can be controlled. Suitable processing technology can be used to make the starch more resistant and consequently behave like fibre.

Processing does not decrease the nutritive value of oats significantly.However, milling and cooking appear to produce significant changes in the digestibility of starch in oatmeal products, leading to different glycemic and insulinemic responses. Steel cut and large flake hot meal porridges, muesli and granola consistently demonstrate medium to low glycemic responses.

Millets

The term 'millets' refers to a group of small seeded, annual cereal grasses. They include sorghum (Jowar), pearl millet (Bajra), finger millet (Ragi), foxtail millet (Kakum), proso millet (Chena), little millet (Kutki), kodo millet (Kodon), and barnyard millet (Sanwa). These millets had been used extensively during ancient times in India until they were replaced with white rice and wheat. India not only cultivated several millets, but is probably the country of origin for barnyard, little, kodo and foxtail millets. Currently, 'millets' have gained popularity and are more easily available in the health foods' section of stores. This change has come about because of awareness about their health benefits.

Nutritionally, millets are undoubtedly superior to white rice and refined wheat. Proso, foxtail and pearl millet contain almost two-fold higher protein and proportions of essential amino acids content (11-12 g%) as compared to rice (around 7%). Millets like other cereals are deficient in lysine, but are good sources of sulphur containing amino acids. Moreover, the mineral content of millets are much higher, e.g. barnyard millet has four- fold higher minerals as compared to white rice. Little millet and pearl millet are rich sources of iron (9.3, and, 8.0 mg% respectively compared to 0.7 mg% in white rice). Proso, kodo and pearl millet contains higher levels of copper compared to rice and wheat. Finger millet tops with the highest content of calcium amongst all cereals. In addition, finger millet and pearl millet are better sources of dietary fibre (11 g %). Millets provide more thiamine, riboflavin and folic acid than rice.

Apart from these nutritional advantages, millets contain many other healthy phytochemicals which are unique to each millet. More than 50 phenolic compounds belonging to several classes, phenolic acids and their derivatives, dehydrodiferulates and dehydro-triferulates, flavan-3-ol monomers and dimers, flavonols, flavones and flavanonolshave been identified in whole kodo, finger, foxtail, proso, little and pearl millets. Pigmented sorghum and finger millet contains anthocyanins and condensed tannins. Finger millet seed coat is a rich source of phenolic compounds. Research is however needed on phenolic compounds present in millet to examine their bioavailablility, metabolism and health contribution to humans. The phenolic compounds present are very different from the ones present in fruits, vegetables and tea (Dayakar et al., 2016; Chandrasekara & Shahidi, 2011; Chandra-sekara & Shahidi, 2010; Shahidi & Chandrasekara, 2013; Dykes & Rooney, 2007). Unpolished millets may have higher levels of fibre, protein, fat, vitamins, minerals and other beneficial compounds. It is unclear whether the new Indian database contains values for polished or unpolished millets. There is an urgent need to create data base for unpolished millets as some of these are available in the Indian market.

To study the nature of millets available in the markets of Chennai, a market survey was conducted by Madras Diabetes Research Foundation (MDRF). Samples of milletswere collected and their morphological features

were studied under stereozoom microscope. Most of the millets were found to be highly polished. Like white rice, polished millets too are fibre depleted, starchy, with higher level of glycemic carbohydrates. Consumption of these kinds of polished millets, like other refined grains, may increase the glycemic load of the diets, may elicit higher glycemic responses and increase the risk for type 2 diabetes. Available carbohydrates in millets are lower as compared to rice but higher than wheat. All millets are not suitable for diabetics as some of them have very high glycemic indices, especially the cooked preparations. While formulating value added products there is a need to look at the glycemic index of the prepared product. Resistant maltodextrin, defatted soya meal, fenugreek fibre are some of the ingredients which can be used in such products to reduce the glycemic index. Likewise processing technologies which can alter the starch structure in a way to reduce its glycemic response should also be adopted by the industry during new product formulation. Unpolished millets should be used by the industry as these are nutritionally superior.

There are several health benefits of millets. Being gluten free, millets are suitable for people with celiac disease. Glycemic Index of millets have yielded contradictory results. Few studies indicate in vitro alpha glucosidase, amylase, aldose reductase, collagen glycation, cancer inhibitory properties of millet phytochemicals which may be beneficial to health. There are few animal feeding trials which support blood glucose, cholesterol lowering, wound healing property of millets. However, to confirm functional benefits, human intervention trials are required. Studies at MDRF have shown higher glycemic index values for finger millet based preparations. Finger millet based extruded snack and vermicelli with added soluble fibre exhibited medium glycemic index (Shobana et al., 2017). Long term human intervention trials are required to establish the functional benefits of millets. There is also a need to develop and follow standardised protocols for studying glycemic properties of foods and diets.

Section 3
Trends In Whole Grain Production And Consumption

3.1: Production

Maize is perhaps the cereal with the highest production in the world though all of it is not consumed by humans and a part of it goes for industrial usage and as animal feed. This is followed by rice and then wheat production. In fact,the crop with the highest production in the world issugarcane(FAOSTATS, 2015). The picture is similar in India where sugarcane production is the maximum followed by rice and wheat. From 1960 to 2015, the production of these crops increased significantly in India. The production of millets has however remained almost unchanged.The Green revolution in India started in the early 1960s and brought about an increase in the production of cereal grains especially wheat and rice. Agronomic technology improved and the country could become self-sufficient in food grain production. India is now one of the largest producers of cereal grains in the world. It has been seen that with increase in net per capita production of food there has been a decline in child undernutrition in the country from 1975 to 2013. However, undernutrition and micronutrient deficiencies still afflict the population. There is also a rise in prevalence of obesity and associated disorders like diabetes, hypertension and other cardiovascular diseases.

India is the 4th largest producer of coarse grains in the world but its production is around only 4% of the total quantity of grains produced in the world. Its production hasn't gone up significantly in the last few decades, as compared to rice and wheat, whose production nearly quadrupled. Coarse grains are mostly grown in Karnataka, Rajasthan and Maharashtra where the temperatures are high and there is scanty rainfall. These grains are also known as 'dry land crops'and are perhaps the best options for crops which are economically viable to grow in the agricultural scenario which has been affected by climate changes. They are less sensitive to soil deficiencies.

3.2: Intakes of Whole Grains

Cereal grains have been a major component of human diet for thousands of years and have played a significant role in shaping human civilization. Around the world, rice, wheat, and maize, and to a lesser extent, sorghum and millets, are important staples critical to daily survival of billions of people. Typical Indian diets have a high proportion of carbohydrates (60-80%) as compared to fats and proteins. The primary source of carbohydrates is cereals followed by pulses, starchy root vegetables and simple sugars. If the intake of carbohydrates is more from whole grains, then besides energy, consumers also get the benefits of other nutrients like fibre, minerals and B vitamins. However, over the decades it has been observed that whole grains have been partially replaced by refined grain products.

In India grains are an important component of the diet of people. Surveys in early 1950s

showed that millets or coarse grains were a significant part of the grains consumed. The proportions however gradually decreased particularlyin the urban population with increase in the intake of rice and wheat and decrease in the consumption of coarse grains. This shift was probably helped by the green revolutionand government policies of that time which encouraged production of wheat and rice to provide food security.

Another shift or transition has been from consumption of whole grains to refined grains and their products. This is probably because a greater variety of food products like bread, biscuits, and other bakery items can be produced with refined flour and they taste better as well. Consuming a healthy diet throughout life helps prevent malnutrition in all its forms as well as a range of noncommunicable diseases and conditions. Easy availability of processed food, rapid urbanization and changing lifestyles have led to a shift in dietary patterns. People are now consuming more foods which are high in energy, fats, free sugars or salt/sodium.Many do not eat enough fruit, vegetables and dietary fibre rich whole grains.

Some processing is inevitable to make whole grains consumable. Excessive processing however strips the grain of most of the nutritional benefits. Although there is a value addition when the whole grain is processed to make a product, the nutritive value may significantly decrease unless care is taken to enrich the final product with the lost nutrients. In some countries, it is mandatory to replace the nutrients which are getting removed during processing of the raw food.

The contribution of different cereals to dietary energy has also changed over the years. Rice contributed to 33.5% of dietary energy in 1963 as compared to 28% in 2013. Contribution of wheat has increased from 12.1 % in 1963 to 21 % of dietary energy in 2013. However, during the same period the contribution of millets to dietary energy has decreased from 6.5 to 2.7%, and that of sorghum alone from 7.7 to 1.3% (NNMB, 2012, 2013-2015).

Due to advanced milling and processing technologies to improve shelf life of the packaged grains, today the refined grains and their products (devoid of nutrient dense bran and germ) dominate the market globally. The available databases like National Nutrition Monitoring Bureau (NNMB) and National Family Health Survey (NFHS) do not segregate the grain consumption into whole grain and processed. India is one of the top countries with high intake of refined grains consumption. Evidence from the cross-sectional study, Chennai Urban Rural Epidemiological Study (CURES) showed that diets continue to be high in carbohydrates, the major source of energy (Urban 64% energy and Rural 78% energy). Refined grains provided almost half of daily calories in this urban population and two thirds in rural. White rice, a high glycemic index (GI) grain, is the main component of the diet. Median consumption of the rural respondents was higher for refined carbohydrates but less for millets and whole cereal milled millets than their urban counterparts. Glycemic load (GL) is the product of glycemic index (GI) and available carbohydrates in food. If a weighted average of glycemic indices of different foods is taken then, the Indian diet seems to have a high GI as

well as GL(Atkinson et al., 2008; Radhika et al, 2011; Sowmya et al., 2016; Narasimhan et al,2016)

Whole grains have a medium glycemic index. Although a high glycemic load is found in the typical diets,it does not mean that the solution lies in not eating cereals which are the staple in India. There is an urgent need of finding ways and means of processing them in such a way that the glucose absorption levels can be reduced (Henry, 2007).This is because high GL dietsare associated with dyslipidemia (low HDL), metabolic syndrome and risk of type 2 diabetes in Indians. The GI of brown rice (medium GI food) was found to be lower (57.6), than undermilled rice (73) and white rice (79.6) and could possibly reduce the GL.Undermilled or hand-pounded ricemay have greater quantities of other nutrients but has a glycemic index like that of white rice (Shobana et al., 2016). Grinding or breaking the grain tends to increase the glycemic index. As more of starch is exposed and available for digestion and absorption, flours and batters made of brown rice become like products made with white rice. Whole grains need to be 'intact' for keeping GI lower. For example, when the whole grain wheat was used as whole wheat flour chappathi, the GI was not significantly different from that of white rice (Average GI of Chappathi: 63.7 vs white rice: 75.6). Also, GL/serving [100 g cooked] of 'wholegrain milled' [33.1] and white rice [26.8] is similar. Thus, it is important to encourage the consumption of 'intact whole grains'.

Average change in interstitial glucose concentration from baseline of overweight participants fed white rice, brown rice and brown rice with legumes demonstrated that brown rice and brown rice with legumes had a similar effect on glucose levels while these were lower than white rice levels (Mohan et al, 2014). Further research is needed on the combinations of foods which can lower the glycemic index of the meal as such. At the same time the products in the markets, making unsubstantiated health claims, need to be regulated. Any product which has been pre-cooked, may have a higher glycemic index than otherwise claimed.

Section 4
Dietary Guidelines For Whole Grain Consumption

Dietary guidelines given by different countries encourage people to consume whole grains. Increase in whole-grain intake can be accomplished by replacing refined grains with whole grains and their products in the diet. However special care needs to be taken to limit the intake of products which are high in saturated fats, added sugars, and/or sodium, such as cookies, cakes, and some snack foods. Grains with small amounts of added sugars and saturated fats can fit within healthy eating patterns. Whole grains and minimally processed grains of brown rice, barley, oats, fibre-rich whole wheat, millets, grain pulses are preferred.

Many countries use FAO food based dietary guidelines to promote the intake of whole grains. Several countries give national recommendations to consume whole grains and foods containing whole grains. France, Great Britain, Switzerland, The Netherlands and Australia recommend the preference for whole grains over refined grains. The United States recommends at least half of cereal intake to be consumed in whole grain form, equivalent to at least 3 ounce equivalent servings of whole grain foods per day for individuals over 9 years. The American Diabetes Association (ADA), 2016 recommends that whole grains should constitute at least half of the grains in the diet. Grain legumes can provide similar health benefits and increase the intake of protein. Canada also recommends that out of 6-7 servings of cereal grains and their products, half the servings should be in whole grain form. Even the dietary fibre intake guidelines for adults, state that whole grains are a source of dietary fibre and should be consumed to meet the requirements (WHO, 2003; EFSA, 2010; Health Council of The Netherlands, 2006; USDA 2015; French Agency for Food Safety, 2002; 49. The Swiss Society for Nutrition, Minister of Health Canada, 2011; National Health Service, 2011).

The Whole Grains Council launched stamps in 2017 to be used on food products for the benefit of consumers to identify whole grain products. There are three types of stamps - one indicating that all (100%) of the grain used in the food product is whole grain (i.e. minimum 16g or more per serve); one which has 50% or more of the grain as whole grain (i.e. minimum 8g or more per serve); and one which is a basic stamp with product containing significant amount of whole grain but less than 50% (i.e. it should still have a minimum 8g of whole grain or more per serve).

Dietary guidelines for Indians (NIN, 2011) recommends the use of a combination of whole grains, grams and greens. Cereals, millets and pulses are a good source of most nutrients and

whole grain cereals and millets should be consumed as a source of energy, protein, fibre, minerals and vitamins.

India is undergoing rapid nutritional transition, resulting in excess consumption of calories, saturated fats, trans fatty acids, simple sugars, salt and low intake of fibre. Such dietary transition and a sedentary lifestyle have led to an increase in obesity and diet-related non-communicable diseases (type 2 diabetes mellitus [T2DM], cardiovascular disease [CVD], etc.) predominantly in urban, but also in rural areas. The National Dietary Guidelines Consensus Group (Misra et al, 2011) included reduction in the intake of carbohydrates, preferential intake of complex carbohydrates and low glycemic index foods and higher intake of fibre, among other recommendations. While these guidelines are applicable to Asian Indians in any geographical setting, they are particularly applicable to those residing in urban and in semi-urban areas. Proper application of these guidelines will help curb the rising "epidemics" of obesity, metabolic syndrome, hypertension, T2DM, and CVD in Asian Indians.

Section 5
Value Added Products With Health Benefits

There is under consumption of whole grains in most countries of the world. Surveys show large gaps between whole grain recommendations and intake globally among adults. Denmark is perhaps one country where the gap between intake and recommendation (75g per day) is not that wide, probably due to a promotion program being actively followed in the country.

The agro-food sector is the largest manufacturing sector whose products can be considered for value addition. The ageing population and changes in lifestyle and dietary patterns have increased the need for “food for health” and “adding life to years”. There is an urgent need to develop foods which are healthful for the consumers. While processing to manufacture value-added products, care must be taken to avoid loss of nutrients and phytochemicals which offer health benefits. Ingredients added to the food product shouldn't make the food product unhealthy. An attempt should be made to make foods with functional benefits beyond the provision of the requisite nutrients to the body. Consumer concerns over food safety and environmental issues need to be kept in mind and should be addressed in business plans for value-added products. Production of such food should be sustainable. In addition, consumers need food they can trust.

Today's consumers are increasingly conscious of the impact of diet on their health and well being. Surveys have indicated that nearly 83% of global consumers consider 'diet and nutrition' important to overall well being (Datamonitor, 2013). The search for foods with additional health benefits, can be easily addressed through producing value added products. Food products containing added nutrients and ingredients may promote or support overall health and wellness in a variety of ways to benefit different organs like heart, bone, digestive system, eye, brain and muscle. Value-adding food ingredients help deliver benefits in weight management and support healthy blood glucose levels, sports performance, muscle health, cardiovascular health and much more.

Whole grains may be difficult to sell through the Public Distribution System (PDS) as these become easily infested with insects and do not have a long shelf life. Most millets in whole grain form do not find acceptance by the consumer. Hence value added products having longer shelf life and in a form more acceptable to the consumer are needed. Although the main aim of processing is to improve appearance, taste, flavour, to decrease anti-nutrients (bioavailability) and to improve shelf life, an effort needs to be made by the industry to conserve the health-protective nutrients and phytochemicals of whole grains.

5.1: Whole Grain Products

Grain processing is an ancient technology used not only in India but other parts of the world as well. Each grain is processed differently based on the targeted end product. Whole grains are consumed in numerous ways. Some grains are

eaten raw, or cooked whole, or germinated and eaten after processing. Few grains, either singly or in combination with other grains, are ground, with or without water, for preparation of various products.

Products labelled as 'whole grain' must contain 100% of the original kernel – bran, germ, and endosperm. A food providing at least 8 g of whole grains/30-g serving of food is defined as a food providing substantial amount of whole grains by the Dietary Guidelines for Americans.

Eating optimally milled brown rice has the advantage of delivering the much needed fibre and micro-nutrients present in bran layers in the diet. However minimally polished rice grains cannot be stored for long as lipase starts reacting with oil content in bran layers producing free fatty acid. Technological intervention in arresting this reaction has been successfully demonstrated by Council of Scientific and Industrial Research -Central Food Technological Research Institute(CSIR-CFTRI). Optimization of industrial scale hydrothermal treatment (HTT), continuous LSU drying and abrasion polishing result in a process for acceptable optimally milled brown rice with maximum retention of nutrients and nutraceuticals having 6-8 monthsshelf stability.

Shelf stable roti from non-wheat cereals and millets and imparting characteristics to the flour which enable it to be rolled out like a roti (without addition of gluten) has also been developed. Malting of rice, wheat and sorghum to increase the availability of GABA has been successfully completed. Germinated pulses, with better nutritional profile, generally need a long time to cook. A technology for preparation of “quick cooking, germinated and dehydrated pulses” has been successfully developed for pulses like bengalgram, moth bean and peas. Whole grains have also been used to prepare dry soup mixes from minor pulses like moth bean and horse gram without the typical “beany” flavour.

Healthy drink mix, porridges and *halwa* from a mixture of many whole grains have been developed catering to requirement of all age groups. Ready to cook (RTC) and Ready to eat (RTE) flakes from many grains have been developed adding variety and convenience to the basket of technologies. Vermicelli noodles from many grains have also been developed. Finger millet (Ragi) is traditionally consumed by making the flour into dumpling (“mudde”) by cooking the flour in water with constant stirring, which is a time consuming and laborious process. Convenience flour which reduces not only the drudgery but also cooking time has been developed.

Rice is known to digest quickly thus increasing the blood glucose level. Slow-digesting, low carbohydrate rice has been developed which is targeted at diabetic patients. CFTRI has also focused on preparation of many traditional foods from whole grains. Not only have the technologies been developed, machinery for milling of various grains have also been developed. Design drawings of parboiling and drying plant, *papad* press (hand and leg operated), maize dry milling plant, tiny rice mill, tiny millet mill, simple *dal* milling systems, to mention a few, are available for joining the “Make in India” movement.

5.2: Multi Grain Products

Multigrain foods are high in complex carbohydrates and protein. Complex carbohydrates break down slower so they can provide energy over a longer period of time. In addition, multigrain products contain other nutrients, like fibre, vitamins and essential minerals like magnesium, copper and iron. As each grain has its own nutrient profile, combining many grains in a single product brings together their goodness making for a nutritious product. Several multigrain products are available on market-shelves.

Value Added Multi Grain Products

Multi Grain Flour	Diabetic Rice
Multi Grain Pasta	Composite Lentil Chips
Multi Grain Infant Food	Pulse Based Soup
Multi Grain Flakes	Millet Pancakes
Multi Grain Bread	Millet Vermicelli/Pasta
Multigrain Biscuits/Crackers	Millet Puffed or Popped
Multi Grain Porridge	Whole Grain in Ice-creams
MultI Grain Snacks	Whole Grain in Chocolates
Infant Food Formulations	Instant Mixes for Traditional Foods
Halwa Mix Formulation	Enteral Food Formulations
Whole Grain Drink Mix	Ready to Eat Snacks with Coarse Grains

Source: CSIR-CFTRI, MDRF

Different types of grain processing techniques have been used to prepare novel food products including: Brewing, Cooking, Dehulling, Dry and wet grinding, Extrusion, Flaking, Germination, Grinding, Malting, Milling, Parboiling, Popping, Puffing and Refining.

5.3: Fortified Products

Health advantages of some of the constituents of whole grains, especially those of micronutrients are lost on account of different types of industrial processing especially milling and degerming. For example, processing removes almost all the B vitamins and minerals such as iron and zinc. This realization has led to use of food technology for restoration or fortification of staple cereals with micronutrients. Today investment in food fortification is considered as the best welfare measure as it has eliminated deficiencies of many vitamins and minerals in the industrialized countries. Several countries have mandated fortification of wheat flour with

iron and folic acid to prevent and control iron deficiency anemia and neural tube defects, respectively.

Based on the global experience, FAO/WHO has suggested guidelines on food fortification with micronutrients. For certain nutrients like iron, bioavailability is a concern. Bioavailability depends on the extraction rate and to overcome this, novel iron fortificants such as sodium iron EDTA, ferrous bisglycinate and various encapsulated and micronized iron compounds have been suggested. The technology of industrial processing of rice to produce whole grain rice or brown rice is simple, butthis rice has limited shelf life. Fortification of rice is done either by coating the grain with an appropriate formulation of micronutrients or a rice-based extrusion technology. Radhika et al (2011) studied the impact of micronized ferric pyrophosphate (MFPP) supplied through extruded rice kernels in a rice-based meal on iron status of children participating in the midday meal (MDM) scheme in India. Iron stores improved and iron deficiency was reduced among the school children.

Many governments in the West have taken the decision to fortify white wheat flour. It is mandatory in north and south Americas, Australia, parts of Africa, while in other countries of Africa it is voluntary. In India and China also it is voluntary. Major concerns when considering whole flour fortification with iron are the poor absorption when added towhole-grain flour, because of presence of phytic acid in the flour. Phytic acid hinders iron absorption. It also creates sensory problems causing the darkening of the product. There are also interactions between the added micronutrient and the food vehicle which may affect the nutrient bioavailability.

Biofortification is another technology which has been used to produce fortified cereals including rice, wheat, maize and millets. Millet is unusually drought resistant and consequently there is a progressive increase in the use of these grains as a human food staple, especially in large areas of India and sub-Saharan Africa. Pearl millet fortified with iron and zinc was shown to increase absorption of minerals in young children (Kodkany et al, 2013). Quantities of both iron and zinc absorption from biofortified pearl millet, fed as the major food staple, was more than adequate to meet the physiological requirements for these micronutrients. Provitamin A-biofortified maize increased serum β-carotene, but not retinol, inmarginally nourished children in a cluster-randomized trial in rural Zambia (Palmer et al, 2016). Iron-biofortified rice improved iron stores of317 non anemic Filipino women (Haas et al, 2005).

Fortification of coarse cereals is being attempted through bio-fortification (selective breeding). Bio-fortified pearl millet 'Dhanashakti' with 71 mg/kg iron and 40 mg/kg zinc has been introduced for cultivation in Maharashtra in 2012 and later in 2013 across India (Finkelstein et al, 2015).

Thus, fortified whole grain has the potential to improve intakes of vitamins and minerals and may work synergistically to contribute to the

health benefits. More research is needed to better understand the effects of these individual components on health outcomes.The potential health benefits of whole grain fortified products greatly depends on the chemistry between the endogenous phytonutrients and the micronutrient fortificants.

Diets may also be modified to improve the absorption of certain nutrients. A study by Nair et al (2013) concluded that simultaneous ingestion of guava fruit with a habitual rice-based meal enhanced iron bioavailability in adolescents. Similarly about 150g of papayahas been shown to improve iron bioavailability from maize meals in Venezuela. The data presented indicated that the amount of dietary iron did not reflect the net amount of iron absorbed by the individuals and that ingredients of a meal such as beef, fish and fruits were paramount to obtain a reasonable utilization of the non-heme iron (Layrisse et.al, 1974).

Thus, while deciding to use fortification as a strategy to combat malnutrition, the first step is to measure the magnitude of the problem and the groups affected by the deficiency of the particular nutrient. Then the adequate form of the nutrient and vehicle should be selected, to obtain a bioavailable form of the nutrient in a frequently consumed food item without changing the taste, appearance or cooking characteristics of the final food item or complete meals containing it, to assure acceptance by consumers. Before implementation, bioavailability studies should be conducted for the fortified food item and for complete meals especially typical or traditional meals, followed by field studies and pilot tests. Once implemented, the program should be monitored and evaluated continuously, and the impact on health assessed periodically. Other key elements for successful implementation of food fortification programs include the presence of a viable food industry; available channels for food marketing and distribution; a health care system to identify and monitor micronutrient malnutrition in the population; institutions for education, and evaluation of the impact of the program; and continuous and effective input into the planning, implementation, monitoring and evaluation of the intervention to ensure sustain ability of the intervention.

5.4: Enriched Foods with Value Added Ingredients

Inadequacies in the diet can be made up for by use of fortified or enriched foods. Food enrichment with value adding ingredients is emerging as an efficient way to improve the nutritional value of a diet. It has been applied for decades to improve the nutritional status of target populations in various countries by adding value to simple, affordable staple foods. Indeed, in many countries fortification of staples is mandatory, to replace nutrients lost through food processing or to reduce the prevalence of identified deficiencies. Consumers today are making more informed choices and paying greater attention to preventive healthcare. This has created a boom in the market for health foods and nutritional supplements of macro and micronutrients in right quantities along with other value added ingredients that offer functional health benefits (Health & Wellness, 2015).

Functional value ingredients for consumers such as proteins, cultures, probiotics, functional carbohydrates and dietary fibre play a key role in the health and wellness recipe. These ingredients significantly improve the nutritional profiles of many foods and beverages delivering benefits of weight management, wellness, increased immunity and digestive health while not compromising on taste and texture of local foods.

Enriched food products are often referred to as functional foods as they provide specific health benefits.To be successful, the functional food products should give tangible benefits to the consumers, which are supported by documented scientific investigations and associated credible claims. The three main parameters for product development keeping consumer choice in mind are - health, indulgence and convenience. A suitable combination of these, increases the possibilities for success.

Table 2: Health Promoting Ingredient Categories

Nutrient/ Phytochemical Category	Nutrient added
Amino Acids, Peptides, Proteins	Amino acids -Arg, Glu, Lys, Leu, Ile, Val; Lactoferrin, Immunoglobulins, bioactive peptides, digestiveenzymes
Fibres	Inulin, Soy Fiber, Polydextrose, Beta-glucan, Resistant starch, Gums such asguar gum, Pectins, Resistant maltodextrin, Psyllium, Insoluble fibres
PUFA/Speciality Lipids	DHA/EPA, ARA, GLA, CLA, Structuredlipids, Pinolenic acid
Vitamins	Vitamins C, B1, B2, B6, B12, Folic acid, Niacin, Biotin, Panthothenic acid,Vitamins A, E, K, D, beta-Carotene(Provitamin A)
Carotenoids	beta-Carotene, Lycopene, Lutein, Zeaxanthin, Astaxanthin
Minerals	Calcium, Magnesium, Zinc, Iron, Sodium, Potassium, Selenium, Chromium
Herbal/Botanical Extracts	Gingko, Ginseng, Kava Kava, Saw Palmetto, HorseChestnut, Echinacea, St. John's Wort, Hoodia gordonii, Rosemary ext
Phytochemicals	Phytosterols, Isoflavones, Lignans, Polyphenols(from berries,olive, tea,tomato, apple,grape, cocoa), Tocotrienols, Isothiocyanates
Probiotics	Lactobacilli, Bifidobacteria, Other cultures
Prebiotics	FOS, Inulin, GOS, Polydextrose, other oligosaccharides (XOS, SOS)
Polyols	Xylitol, Lactitol, Isomalt, Maltitol, Erythritol
Others	CoQ10, Glucosamin, Chondroitin, Lipoic acid , Inositol, Creatine Carnitine, Taurine, SAMe, Choline, Betaine

Section 6
Popularizing Whole Grain Products

Grains constitute 60-70 % of the Indian diet. While it is still difficult to assess the intake of whole grains through diet surveys, sporadic studies available suggest that the population may under consume wholegrain foods due to a numberof reasons – appearance (aesthetics), taste, convenience. As there is convincing evidence that even a small increase in whole grain consumption has substantial benefits at population level, a concerted effort is required to address the complexity of introducing whole grain in the daily diet that consumers find acceptable.

Aligning health and wellness product innovation with consumer lifestyles is critical to fulfilling unmet needs. Globally, consumers realize the important role healthy foods, drinks and dietary supplements can play in their overall well-being. There is however, a gap between interest in functional foods and health and actual purchase behaviour (Data monitor, 2013).In 2015, Data monitor survey revealed that 84% of the people surveyed had a positive response about whole grains, 54% for ancient grains. Whole grains and green tea were perceived to be equally healthful by most (84%) consumers. Among Health and Wellness product offerings, fortified/ functional and naturally healthy products had the largest share, with food intolerance products like gluten-free foods, diabetic foods, lactose-free foods, and other special milk formulas howing the greatest past and predicted growth (Euromonitor, August 2015).

6.1: Barriers to Consumption

For some consumers, nutrition is primary while for others it is secondary. Consumers for whom nutrition is primary are usually those affected by some health problems and hence wanting to choose foods for specific medical purposes. Some are concerned about weight related health issues but can't seem to overcome barriers that prevent attaining a healthy weight. Some others are however, knowledgeable about nutrition and health and can choose foods that enable a healthier life.

Eating is just about sustenance and satisfying hunger for those who consider nutrition secondary. Some others may feel that taste is everything and that eating should always be an enjoyable experience. They either do not believe that there is a direct connection between food and health, or they simply do not care. It is thus more difficult to target this group and improve their eating habits (Health Focus, 2014).

When catering to those who think, nutrition is important, the product needs to be positioned in a way that attracts this segment. For instance, bread can be made into a healthy option by incorporating some the following properties - low fat, made with whole grains, gluten free, no artificial preservatives, no added sugar, good source of fibre/ added fibre, etc. It should have a clean label with recognizable ingredients and give a healthful picture.

The authentic brown rice has intact bran and germ and lowers glycemic response. However, procuring authentic brown rice is difficult in the market. A focus group discussion study conducted by MDRF, Chennai (Sudha et al, 2011) indicated poor acceptance of brown rice due to its sensory attributes like chewy texture and longer cooking time. The rice also had a short shelf life and it easily became infested with weevils. Consumer in urban areas in Chennai considered cooking quality and appearance of the grains as the most important factors when purchasing rice. Education regarding health benefits may help this population switch to brown rice (Kumar et al, 2011). Agricultural scientists have produced an innovative high fibre white rice using classical plant breeding techniques with GI and 24 hr. glycemic response similar to brown rice (Mohan et al, 2016).

There are several reasons why consumers do not accept whole grains and their products. These have been listed in figure 3. Long cooking time and short shelf life make most grains inconvenient to use. Taste, texture, appearance of typical traditional dishes made with whole grains may not be very appealing or digestible for many consumers. Unless consumers are aware about potential health benefits and motivated towards healthy eating habits, they are unlikely to select whole grain products.

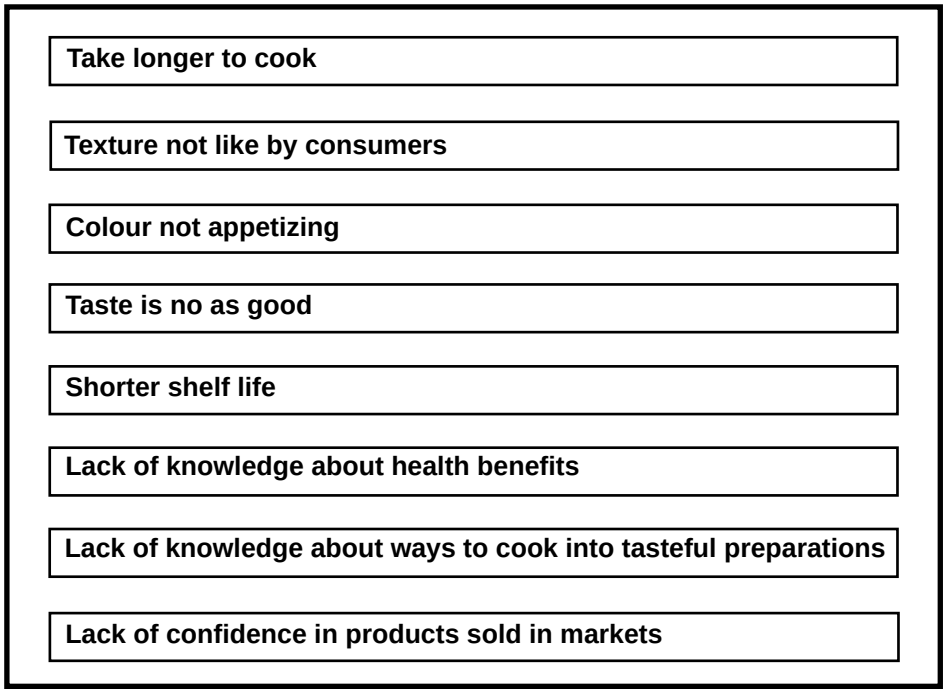

Figure 3: Barriers to Consumption of Whole Grains

6.2: Breaking Barriers

To overcome the barriers to consumption of whole grains there needs to be a three-pronged approach (figure 4) – *technical innovation* in agriculture, post- harvest technologies as well as new food product development; *policy advocacy* to promote production and consumption of whole grains and their products; and, *community awareness.*

Technical innovations to improve post-harvest technologies for storage and production of value-added products of whole grains, development of germinated brown rice or low lipase brown rice with better nutritive value and shelf life, improvement of refined grain composition or texture to mimic whole grain glycemic property and nutritive value, would help in promoting their consumption.

The Government should support the promotion of whole grain consumption by reflecting the intention in policy. Shelf stable brown rice can be subsidised and promoted through the public distribution system (PDS). Farmers and millers can be encouraged to grow and promote brown rice by giving them incentives. The Food Safety and Standards Authority of India needs to provide standards for regulating the labelling of whole grains and their products as well as health and nutrition claims made by the food companies. It is also important that FSSAI defines whole grains and whole grain products for clarity. The consumer should be confident about the veracity of these claims and that is possible only when regulations are strictly implemented.

Consumer awareness can be spread by health and nutrition programs at state and central levels, by conferences, and through involvement of not only the scientific community but also religiousorganizations, schools and colleges (as food habits form during childhood) and food service establishments. Media can play a powerful role in dissemination of information through various channels like radio, television, print media as well as social media like WhatsApp, Facebook, etc.

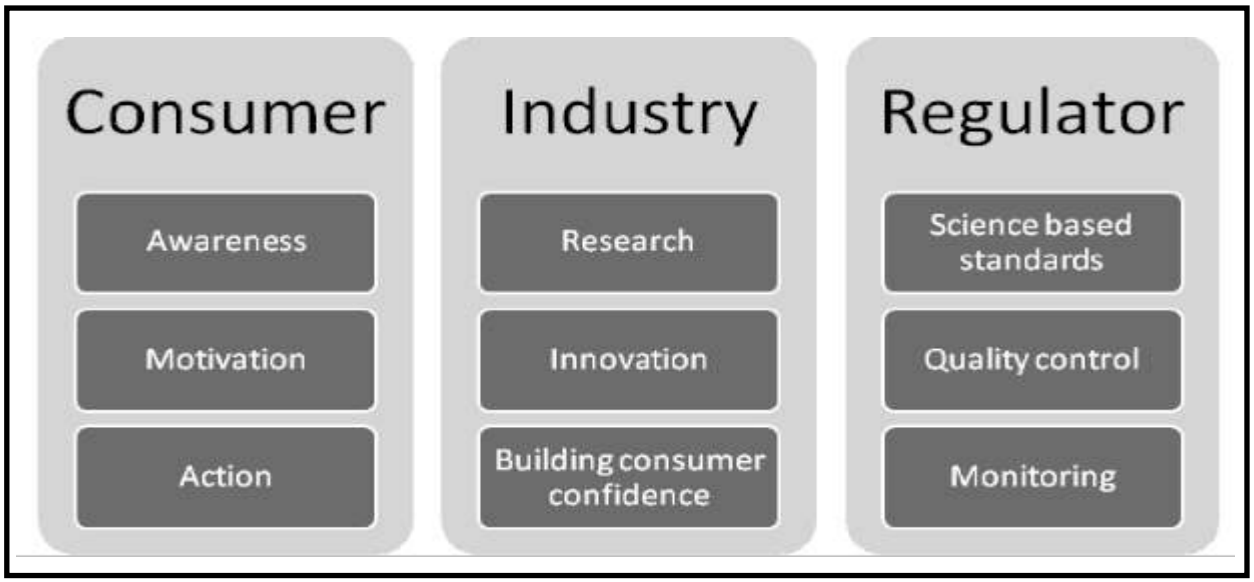

Figure 4: Role of Consumer, Industry and Regulator in Increasing Whole Grain Consumption

The food industry in the 21st century needs to cater to all three aspects -health, convenience and indulgence for a consumer. The consumer wants to eat healthy and foods would need to be altered in their composition by adding healthful ingredients and removing unhealthy components. The challenge is also to provide guilt-free indulgence by making these foods tasty and exotic. It is also important to make them convenient to eat by decreasing preparation time without compromising on quality. For people who need to eat in their workplace the foods need to be non-messy and convenient to carry from home. At the school level, canteens need to serve more of whole grain rich meals. All stakeholders- i.e. canteen owners, teachers, students, parents need to be on board about menu changes being proposed, for them to be acceptable. Teachers can act as trainers for students as well as parents during parent teacher meetings. High fibre foods tend to be more difficult to digest as well, and may lead to flatulence. People wanting to include more whole grains in their diet should be advised to do so gradually so that they slowly get accustomed and digest the grains better. Otherwise it can lead to rejection of the whole grain products because of digestibility issues.

Restaurants also have an important role to play in incorporating healthy ingredients in their dishes. Customers are willing to experiment with their food more than ever before. This presents a novel and challenging opportunity for chefs to churn out new recipes. Traditional recipes of whole grains from different parts of the country can be promoted and popularized. These can also be suitably altered by making them more healthful with value-adding ingredients.

Consumer organisations also need to be more active in promoting healthful eating habits in general and consumption of whole grain products in particular.

Section 7
Conclusions & Recommendations

The country is witnessing a transition in diet and lifestyle. Complex carbohydrate intake is decreasing with simultaneous concomitant increase in refined carbohydrates, salt, saturated and trans- fat laden foods. The intake of beneficial nutrients like fibre, omega 3 fatty acids and MUFA has reduced. Even when mean body mass index (BMI) is in a low range, body fat percent is high among Indians. A high prevalence of abdominal obesity is also seen in both males and females, along with hypercholesterolemia, hypertriglyceridemia and low levels of high-density lipoprotein (HDL) cholesterol. This along with reduction in physical activity levels has contributed to the sharp increase in incidence of diet related non-communicable diseases. Genetic predisposition to these diseases is not under our control, but diet, physical activity and stress management which are the three important components of good health, are modifiable.

Whole grains have been associated with several health benefits. Epidemiological studies have shown their health benefits which include a decrease in risk of cardiovascular diseases (CVD), Type 2 diabetes (T2DM), colorectal cancer, blood pressure lowering and weight management. In the last five decades, there has been an increase in the consumption of rice and wheat and a decrease in the consumption of coarse grains and millets. There has also been an increase in the consumption of processed and refined grains.

Recommendations

- Fortification
  Processing removes important nutrients from the grains reducing the amounts of protein, fibre, almost all the B vitamins, minerals and phytochemicals. Food fortification and enrichment with value-added ingredients seem viable strategies to improve the quality of diets. The potential health benefits of whole grain fortified products greatly depends on the chemistry between the endogenous phytonutrients and the micronutrient fortificants. Use of novel fortificants with better bioavailability have been suggested for products of whole grain.

- Biofortification
  To improve the nutritive value of whole grains, bio-fortification through selective plant breeding and genetic engineering has also shown promising results.

- Definition of Whole Grains
  FSSAI may develop definition of whole grain and whole grain containing products.

- Labelling and Claims
  FSSAI may lay down guidelines for labelling and claims and indicate the minimum amount of whole grain in food product to justify the claim.

- Dietary Guidelines

  Replacing half of the grains consumed daily with whole grains has been recommended by many international dietary guidelines. Eating a variety of grains is also recommended to derive the nutritional benefits of different types of whole grains.

- Consumer Acceptance

- Food industry should produce products that are nutritious and accepted by the consumers.
- Changing food habits is not an easy task and hence promotional measures need to be well thought out. Several strategies are needed to encourage whole grain consumption among consumers. Consumers need to be made aware about the health benefits of whole grains.
- Foods, dishes and meals containing whole grains need to be made more attractive to both adults and children.
- It is important to encourage consumption of intact whole grains to keep the glycemic index low.
- The Government needs to play an important role in encouraging whole grain consumption. Build consumer confidence, it needs to be ensured that claims are substantiated .

- Standard Protocols

  There is also a need for standardisation of protocols for studying glycemic responses of different foods and diets so that results are comparable between laboratories and countries.

- R & D

- Further research is needed on effect of whole grain consumption on gut microbiota and its health benefits.
- Translation of research done in laboratories to guidelines and dietary advice for the population as well as guidelines for the food industry to develop healthier food products is of utmost importance.
- Processing technologies should be developed to increase shelf life of whole grains and their products as also to reduce glycemic index.
- Further research is needed on the combinations of foods which can lower the glycemic index of the meal as such.
- Research should be conducted on novel processing technologies as well as functional ingredients which can help decrease risk of non-communicable, diet-related disorders.
- While developing value- added products the industry has to keep in view the food matrix and the effect of the processing technology on nutrient bioavailability.

Healthy Food Task Force

ILSI India proposes to launch a Healthy Food Task Force which will work in collaboration with government, research organizations and universities for promoting healthy eating among Indians.

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