

## Review

# Use of functional foods for diabetes prevention in China

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**Diabetes is the most important modifiable risk factor for life-threatening diseases. The following conclusions were drawn on the basis of the analysis of different factors: (1) Main reasons for the prevalence of diabetes in China are low dietary fiber, unhealthy life-style, obesity, and genetic factors. (2) All factors that cause diabetes are linked to dietary factors, especially the loss of functional components from brown rice (whole grains) to white rice (wheat flour) especially good rice (wheat flour) for diet is a major factors that cause diabetes. Since the diabetes has become the major public health problem in China strategies aimed at its prevention and treatment are needed. (3) Functional food for dietary uses is the key for diabetes prevention in China, including whole grains foods (brown rice, wheat flour of whole grains, barley, buckwheat, oats and others) as well as functional rice with high resistant starch for dietary purpose. (4) There are a lot of challenges to promote functional foods with whole grains or high resistant starch in China. Our goal is to establish one research center of functional foods with members from the manufacturers, breeding scientists, education, medical and news media, to promote functional foods.**

**Key words:** Diabetes mellitus, functional food, prevention strategies, whole grains.

## INTRODUCTION

Diabetes mellitus (DM) is a major risk factor for cardiovascular disease, and the prevalence of DM is high and is increasing in China as well as in the world (Apostolidis et al., 2011; Reddy and Bhatia, 2011; Zhong et al., 2010). Prevalence of DM is 6.4% (285 million people) of the world's adult population in 2010, in Asia 46.5% (132.455 million), in India (50.768 million), in China (43.157 million), in USA (26.814 million), but likely to affect 7.8% (438 million) of the adult population by 2030 (Yang et al., 2010; Shaw et al., 2010). Chinese residents (224,251 from 25 to 64 years) from 19 provinces in 1994 showed that the prevalence of DM and impaired glucose tolerance were 2.5% and 3.2%, respectively (Pan et al., 1997). The age-standardized prevalence of total diabetes and prediabetes were 9.7% (10.6% among men and 8.8% among women) and 15.5%

(16.1% among men and 14.9% among women), respectively, accounting for 92.4 million adults with DM and 148.2 million adults with prediabetes (76.1 million men and 72.1 million women) in 2008, meanwhile, the prevalence of DM was higher among urban residents (11.4%) than among rural residents (8.2%) (Yang et al., 2010). The prevalence of total diabetes and prediabetes in 2008 were 3.88 and 4.84 times than that of 1994. The prevalence of DM increased with increasing age (3.2, 11.5 and 20.4%) among persons who were 20 to 39, 40 to 59, 60 and above years of age, respectively) and with increasing weight (4.5, 7.6, 12.8, and 18.5%) among persons with a body-mass index of <18.5, 18.5 to 24.9, 25.0 to 29.9, and  $\geq 30.0$ , respectively) (Yang et al., 2010). As compared with placebo, pioglitazone (Hydrochloride) reduced the risk of conversion of impaired glucose tolerance to type 2 diabetes mellitus (T2DM) by 72%, but was associated with significant weight gain and edema (DeFronzo et al., 2011). Therefore, strategies aimed at the preventing DM are urgently needed while treatment of DM has become a major public health problem in China.

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Pharmaceuticals cannot fundamentally solve health problems. Remarkably, the cost of managing DM by Americans in 2007 was \$174 billion (Apostolidis et al., 2011). The cost to medical treatment by Chinese government in 1980 was ¥14.32 billion and in 2007 it was ¥1096.6 billion. A sharp increase of 76 fold, with the medical care costs of ¥844 per capita (<http://wholegraincouncil.org/files/Yu2011conf.pdf>). From Swinbanks and O'Brien, (1993) reports, Japan explores the boundary between food and medicine, the terminology "functional food" has globally been propagated. Functional foods represent one of the most interesting areas of research and innovation in the food industry (Annunziata and Vecchio, 2011). Functional food is not only any healthy food claimed to have a health-promoting or disease-preventing property beyond the basic function of supplying nutrients, but also one of the fastest-growing with the global food industry (Das et al., 2010). Functional foods which are integral components of the diet are understood to contribute added health benefits and are subjected to intense and widespread research in disease prevention. Functional food such as oatmeal, apple, broccoli, tomato, berries, strawberry, orange, grapes, papaya, blackberry, citrus, cocoa, almonds, peanuts, green tea, red wine, garlic and so on, offer the opportunity to prevent chronic diseases such as DM, coronary heart disease, obesity, cancer, hypertension, cardiovascular disease, asthma and so on (Das et al., 2010). Apple may contribute to beneficial effects on health against cardiovascular disease, asthma and pulmonary dysfunction, DM, obesity and cancer (Gerhauser, 2008). Oat bran flour high in beta-glucan had a low glycemic response and acted as an active ingredient decreasing postprandial glycemic response of an oral glucose load in subjects with T2DM (Tapola et al., 2005). The validity of walnut oil in the treatment of type I DM is effective (Rahimi et al., 2011). This review focuses on a wide range of functional foods for diabetes prevention in China and discuss reasons caused DM and also promote new strategies prevention.

## REASONS FOR PREVALENCE OF DIABETES IN CHINA

The International Diabetes Federation (IDF) estimates that DM currently affects more than 223 million people worldwide, and the figure is expected to reach 333 million by 2025, approximately 6.3% of the global population (Wang et al., 2011). Though islet transplantation is ready for widespread use in type 1 diabetes but there is a lot of limitation (Wang et al., 2011). DM is linked with behavioural, environmental, and societal factors such as obesity, aging, urbanization, physical activity, sedentary behaviour, and unhealthy dietary habits (Yang et al., 2008; Yang et al., 2010; Waly et al., 2010), as well as genetic factor (Chen et al., 2010). Common risk factors,

such as obesity, sedentary lifestyle, and western diet between DM and colorectal cancer(CRC), led to the theory that DM might be a causal agent for CRC development; chronic insulin treatment has been linked with increased colorectal tumor risk among type 2 diabetic patients (Giouleme et al., 2011). Type 2 Diabetes Mellitus was associated with an increased prevalence of upper gastrointestinal symptoms and these symptoms appeared to be independently linked to poor glycemic control, as measured by the glycosylated hemoglobin (Kim et al., 2010). The prevalence of total diabetes (92.4million adults) and prediabetes (148.2 million adults) based on survey of 46,239 adults from 14 provinces in 2008 were 9.7 and 15.5%, respectively (Yang et al., 2010). The prevalence of DM and impaired glucose tolerance based on 224,251 Chinese residents from 19 provinces in 1994 were 2.5 and 3.2%, respectively (Pan et al., 1997). Therefore these estimates were higher by a factor of approximately 11 in 2008 or 3 in 1994 than those reported in 1980 (National Diabetes Research Group, 1981). Dietary glycemic index was negatively related to total dietary fiber intakes and the diet rich in vegetables; dietary fiber may decrease the dietary glucose response (Yin et al., 2009). Chinese need 24 to 32 grams of dietary fiber per day as recommended by Chinese Nutrition Society, but there was only 10 to 15 grams of dietary fiber per day.

First of all, the low dietary fiber from whole grain to polished grain foods are key factors that cause diabetes. The food-processing procedures introduced have altered 7 crucial nutritional characteristics of ancestral diets, including glycemic load, fatty acid, macronutrient, micronutrient, acid-base, sodium-potassium ratio, and fiber content (Cordain et al., 2005). An intake of 50 g dietary fiber improves glycemic control, decreases hyperinsulinemia and lowers plasma lipid concentrations in patients with T2DM (Chandalia et al., 2000). Dietary fiber may reduce the risk of death from cardiovascular, infectious, and respiratory diseases, lower the risk of coronary heart disease, DM, and some cancers (Park et al., 2011). The nutrition associated with DM in flour milling process from whole wheat flour to make white flour is loss in turn fiber (89%) and chromium (40%) (<http://realfoodliving.com/faqs/wheat-faqs>). Dietary fiber could not only significantly reduce the body mass and waist-hip ratio in obese patients with T2DM, but also could significantly improve blood sugar, blood pressure, blood lipids and insulin sensitivity in patients (Ran and Liu, 2008). The blood sugar tolerance in common and diabetic mice treated with superfine dietary fiber has an obvious improvement; blood sugar peaks and blood sugar levels in common and diabetic mice after meal are significantly decreased (Xiao and Lu, 2010). Dietary glycemic index was negatively related to total dietary fiber intakes, the diet rich in vegetables and dietary fiber may decrease the dietary glucose response (Yin et al., 2009).

Secondly, unhealthy life-style is one major factor that causes DM. The economic development and associated

lifestyle as well as diet, may explain the prevalent differences of DM between urban and rural areas (Yang et al., 2010). Cereals intake were contributed from 74.6% in 1982 to 61.5% in 2002 in rural areas, but fats intake increased from 25 to 35% in urban areas (Wang, 2005). The time of Chinese adults watching television was 2.1 h every day by reduced physical activity (Xie et al., 2008). Life style intervention including diet and activity decreased the glycemia and satisfaction rate (83.2%) of controlling glycemia of gestational DM (Liang et al., 2011). Moderate manual work can prevent and treat the metabolism disorder of blood sugar and blood lipid as well as metabolic syndrome (Zhao et al., 2011). Smoking men with impaired glucose tolerance or DM appeared more insulin resistant than their non-smoking counterparts (Ko et al., 2007). The appropriate exercise rehabilitation is beneficial in type 2-diabetic patients to improve their glycometabolism and ability of physical activity (Tan et al., 2009). Taijiquan exercise can improve the immune function of T2DM patients (Qi et al., 2008; Liu, 2008). Single bout of exercise can significantly decrease the peak plasma glucose and glucose area under curve but cannot decrease the incremental area under curve in patients with T2DM, especially in those with longer clinical history and greater body weight (Chen et al., 2007).

Thirdly, obesity is a major factor that cause DM. Obesity is associated with hypertension, dyslipidemia, DM, coronary heart disease, stroke, as well as increased all cause mortality (Mohammed et al., 2002). The high risk of both DM and cardiovascular disease associated with obesity in Asians may be due to a predisposition to abdominal obesity, which can lead to the metabolic syndrome and impaired glucose tolerance; about 90% of T2DM is attributable to excess weight (Hossain et al., 2007). Obesity is closely associated with oxidative stress of DM (Espirito and Mazzone, 2008). Waist-to-height ratio shows that obesity is related T2DM etc. for both sexes in Jinan, China (Dong et al., 2011). The altered glucose homeostasis is caused by faulty insulin signal transduction, which results in decreased glucose uptake by the muscle, altered lipogenesis, and increased glucose output by the liver (Zhao and Zhu, 2010). Body mass index was a better predictor of cardiovascular disease and DM than waist circumference in young and middle-aged women (Ying et al., 2011). Obesity, especially abdominal obesity, contributes to many metabolic disorders including metabolic syndrome, T2DM and cardiovascular diseases, and more than one-third of adults are overweight or obese and 10 to 20% of all adults in China are affected by metabolic syndrome (Jian et al., 2010). IRS-2G1057D variant in Han population in Liaoning Province were by measuring body mass index, waistline/hip ratio and other parameters of insulin secretion, as well as insulin action to explore the relationship between IRS-2G1057D variant and T2DM (Kong et al., 2005). For the young patients with type 2 DM, the poor blood glucose control, obesity and

increased triglyceride are the major risk factors for periodontal disease (Jiang et al., 2011). Overweight and obesity can aggravate the coagulation and metabolic disorders of T2DM, which will be aggravated with the increasing seriousness of obesity (Hu et al., 2011). It is an important measure to prevent type 2 DM by controlling weight and a reasonable diet (Zhang et al., 2010). *Gln223Arg* variant in leptin receptor gene may be associated with pathogenesis of obese T2DM (Zhao et al., 2008). Nucleotide 3 057 in LR exon 20 a G to A transversion was found which may be the susceptibility marker of DM in Chongqing population (Tang et al., 2005). Increase in intra abdominal fat depots as well as decrease in femoral subcutaneous fat depots is not only the features of body fat distribution observed in diabetic patients, but also in subjects with metabolic syndrome (Xiang et al., 2004). Insulin resistance caused by high level of resistant links obesity to hypercholesterolemia and T2DM (Cheng and Wei, 2003).

Fourth, the interaction between genetic and environmental factors is a major factor that causes diabetes. *CDKAL1* polymorphisms are significantly associated with T2DM, but these associations vary in different ethnic populations (Dehwah et al., 2010). The prevalence of diabetes is: black (8.5%) > South Asian (8.1%) > Chinese (4.3%) > white (4.2%) (Chiu et al., 2010). African, Hispanic, Native American and Asian descent are vulnerable to DM and its complications (Waly et al., 2010). 12 Gene regions may play important roles in pancreatic beta-cell development and function (Yang and Li, 2010). The genetic variation DG10S478 in the *TCF7L2* gene may be associated with T2DM, in Hefei population, and *TCF7L2* risk allele may predispose to T2DM by impairing  $\beta$ -cell proinsulin processing (Cao et al., 2010). UCP3 gene-55C→T variant is associated with T2DM in northeast China (Liu et al., 2010). In the population of type 2 DM families, only 54G/C polymorphism of *SREBP1c* gene being the mutant type (GC/CC) might be a moderate risk factor of abdominal obesity (Song et al., 2009).

*ADIPOQ* gene and *CAPN10* gene variations might play roles in the risk of DM and hypertension in northern Han Chinese population (Chen et al., 2007; Wang et al., 2009). The 482Ser variant of PGC-1 $\alpha$  conferred the susceptibility to T2DM in the southern Chinese population (Zhang et al., 2007). *PRKCZ* gene may be associated with T2DM in Han population in North China (Li et al., 2003). New genes are found and T2DM can be prevented or cured (Yang et al., 2009).

## MAJOR FOOD CAUSE OF DIABETES IN CHINA

The experience of developed countries shows that the most important contributors to DM are low dietary, unhealthy lifestyle, obesity, the interaction between genetic and environmental factors. The Chinese have an ancient tradition, dating back as far as 2800 BCE, that a

combination of grains (rice, wheat, and millet) should be the basis of every diet.

First of all, loss of the elements content from brown rice to white rice especially good rice for dietary is a major factor that cause DM. Rice is an indispensable staple food for half of the world's population and increasing the concentrations of Ca, Fe, and Zn in rice grains will help alleviate chronic Ca, Zn, and Fe deficiencies in many areas of the world (Zeng et al., 2010). Loss of the elements content from brown rice to white rice is Sr(99.3%) >Cr(99.2%) >Mg(61.8%) >Zn(61.0%) >Mo(60.6%) >P(57.9%) >K(55.9%) >Sn(54.3%) >Mn(55.0%) >Ni(42.9%) >Ba(37.8%) >Al(33.7%) >B(32.5%) >Fe(31.7%) >Ca (31.2%) >Cu(28.1%) >Na(10.8%) >S(9.1%) (Zeng et al., 2009a). The loss of mineral nutrition from brown rice to white rice is P > Mg > K > Cr > Ca > Sr > Zn > Fe > Mn > Mo > Sn > Ni (See Table 1), according to a calculation of 198.7 million tons of Chinese rice yield as well as, 697.9 million tons of global rice yield in 2010 based on Zeng et al. (2009a,b). Some elements (Cr, V, Rb, Cs, Se, Zn, Fe, Ni, Co, Mn, Cu, and Mg) have shown to play a role in DM (Choudhury et al., 2008; Kazi et al., 2008; Liu et al., 2000), especially Cr associated with T2DM, and gestational diabetes patients require more than 200 µg daily of supplemental Cr (Anderson, 1998; Anderson et al. 2011; Polansky and Bryden, 2011). Magnesium (Mg) is involved in the interaction of more than 300 enzyme reactions in the body; Mg intake was inversely longitudinally associated with incidence of DM in young American adults (Kim et al., 2010). Daily intake of a vitamin D fortified yogurt drink, either with or without added calcium, improved glycemic status in T2D patients (Nikooyeh et al., 2011). Low serum potassium concentrations in African Americans may contribute to their excess risk of T2DM relative to whites (Chatterjee et al., 2011). Strontium fructose 1, 6-diphosphate relieves DM induced male hypogonadism in rats and is superior to that of testosterone propionate (Zhang et al., 2008). The average chromium intake in residence in Hubei province was 53.17 µg, and that of urban and rural residents was 48.70 µg and 55.47 µg, respectively; Cr intake in 40.20% of residents living in Hubei province was under the minimum level suggested by the Chinese Nutrition Society (Huang et al., 2009). The Cr enriched sprouted brown rice have the function of lowering the blood sugar of DM mice (Ding et al., 2008). The medium and high doses of oral magnesium in rats reduced the fasting blood glucose by 11.3 and 21.9%, and the insulin level by 25.4 and 38.7%, respectively (Zhong et al., 2011). The supplement of zinc has inhibition effect on vascular endothelial growth factor expression, preventive and therapeutic effects on diabetic retina in rat (Dong et al., 2010). There are apoptosis and abnormal Na<sup>+</sup> and K<sup>+</sup> contents in retinal tissue of DM rats, and these changes may be one of pathological bases of diabetic retinopathy (Tang et al., 2006). Manganese supplement, which is

related to the acceleration of anti-oxidation action, can help recover myocardial injury of T2DM (Kang et al., 2007). The domesticated rice may have first appeared as far back as approximately 8,200 to 13,500 years ago in the Yangtze Valley of China (Molina et al., 2011) however; functional components have clearly changed from brown rice approximately 100 to 13,500 years ago to white rice about 0 to 40 years.

Secondly, loss of some nutrition vitamins and functional components from brown rice to white rice especially good rice for dietary also is a major factors that cause DM. The loss of vitamins and functional components from brown rice to white rice is with respect to riboflavin (B2, 84%) >thiamine (B1,83%)> total flavones (79.20%)>γ-aminobutyric acid (GABA,78.82%) >fat (77%) >niacin (B3,68%) >pyridoxine (B6,68%) >dietary fiber (57%)>total alkaloids (40.55%)> pantothenic acid (B5, 32%)>resistant starch (19.53%) (Zeng et al, unpublished data). The loss of vitamins and functional components from brown rice to white rice is also with respect to dietary fiber > total flavones > total alkaloids >GABA > pantothenic acid > pyridoxine > thiamine >riboflavin, according to calculation of 198.7 million tons of Chinese rice yield as well as 697.9 million tons of global rice yield in 2010 based on Zeng et al. (2010) and USDA Nutrient database (Table 2). Riboflavin inhibits the protein expression of TGF-β1 and PAI-1 in renal tissue of STZ-induced diabetic rats; however it may alleviate the pathologic changes and play an important protective role in diabetic kidneys (Wang et al., 2010). Many people with DM and syndromes as well as beriberi were caused by thiamine deficiency (Thornalley, 2005). Among 10 flavonoid glycosides, baicalin and breviscapine have potentially preventing effects for diabetic pathogenesis by inhibiting the 4 important pathways (Cheng and Shi, 2010). Flavonoids of Rose and extract from sweet potato vines have significant effects of lowering blood-glucose action on diabetic mice and were probably worthy to be developed into medicines for DM (Gao et al., 2011). Niacin could not only regulate insulin secretion but also improve SOD concentration and repair the damaged islets β-cells (Feng et al., 2008).

The occurrence of diabetic peripheral neuropathy might be related to VB6, and might be related to blood glucose and lipid (Zhang et al., 2010). Dietary glycemic index was negatively related to total dietary fiber intakes, the diet rich in vegetables and dietary fiber may decrease the dietary glucose response to *Dendrobium nobile* Lindl (Yin et al., 2009). Alkaloids could significantly decrease the blood glucose in alloxan induced hyperglycemia in rats, and its mechanism is due to protecting the pancreatic islet (Huang et al., 2009).

Thirdly, the loss of nutrition from whole grains to white flour especially good flour of wheat for dietary is also a major factor that causes DM. The loss of nutrition in flour milling process from whole wheat flour to make white flour is as follows: zinc(98%) > phosphorus (91%)

**Table 1.** The loss of elements content from brown rice to white rice.

Elements	Elements content loss (%)	China (tons)	Globe (tons)	Elements	Elements content loss (%)	China (tons)	Globe (tons)
Strontium(Sr)	99.3	6,955	24,404	potassium (K)	55.9	285,507	1,001,780
Chromium(Cr)	99.2	17,977	63,076	manganese (Mn)	55.0	1,395	4,896
Magnesium(Mg)	61.8	380,174	1,333,945	tin (Sn)	54.3	229	804
Zinc (Zn)	61.0	4,045	14,194	nickel (Ni)	42.9	162	571
Molybdenum(Mo)	60.6	327	1150	iron (Fe)	31.7	1,934	6,787
Phosphorus (P)	57.9	422,921	1,483,933	calcium (Ca)	31.2	9,551	33,511

**Table 2.** The loss of nutrition of vitamins and functional components from brown rice to white rice.

Functional components	Components loss (%)	China (tons)	Globe (tons)	Functional components	Components loss (%)	China (tons)	Globe (tons)
Dietary fiber	57.0	3,964,955	13,926,233	Pantothenic acid(B5)	32.0	950	3,332
Total flavones	79.2	158,648	556,661	Pyridoxine (B6)	68.0	688	2,415
Total alkaloids	40.6	54,652	191,957.85	Thiamine (B1)	83.0	491	1,725
GABA	78.8	19,942	69,971	riboflavin (B2)	84.0	155	545

**Table 3.** The losses of nutrition from whole grains to white flour of wheat.

Nutrition components	Components loss (%)	China (tons)	Globe (tons)	Nutrition components	Components loss (%)	China (tons)	Globe (tons)
Phosphorus	91	880,356	5,118,350	dietary fiber	89	13,510,200	78,476,640
Potassium	77	789,151	4,588,091	Niacin	81	6,341	36,864
Magnesium	85	233,411	1,357,042	Thiamine	77	1,699	9,880
Calcium	60	26,886	156,312	Pyridoxine	72	1,075	6,252
Zinc	98	13,838	80,455	Riboflavin	67	384	2,233
Manganese	86	13,143	76,412	Pantothenic acid	50	29	167
Iron	75	5,394	31,363				

> fiber (89%) = cobalt (89%) > manganese (86%) = vitamin E (86%) > magnesium (85%) > niacin (81%) > sodium (78%) > potassium (77%) = thiamine(77%) > iron (75%) > pyridoxine (72%) > copper (68%) > riboflavin (67%) > folic acid (67%) > calcium(60%) > pantothenic acid (50%) >

molybdenum (48%) > chromium (40%) > choline > (30%) > selenium (16%) (http://realfoodliving.com/faqs/ wheat-faqs). The loss of elements content and vitamins in flour milling process from whole wheat flour to make white flour is dietary fiber > phosphorus >

potassium > magnesium > calcium > zinc > manganese > niacin > iron > thiamine > pyridoxine > riboflavin > pantothenic acid, according to calculation based on USDA nutrient database and 668 million tons of global and China wheat yield in 2010 (Table 3).

## STRATEGIES OF FUNCTIONAL FOODS FOR DIABETES PREVENTION IN CHINA

DM is one of the severe diseases threatening human health. Prevention and control of DM depend on adopting a balanced diet, including protein, healthy fats, and sufficient fibre from whole grains, legumes, vegetables and fruit.

First of all, functional food with whole grains is the key to diabetes prevention in China, consumption of whole wheat flour or brown rice account for 1% but white flour or white rice account for 96%. The whole-grain cereal products with beneficial influence on postprandial plasma glucose and insulin responses can be tailored by fermentation and enclosure of high-amylose and/or high-beta-glucan barley and oat kernels (Alminger and Eklund-Jonsson, 2008). Whole grains (endosperm, bran and germ) play important roles in disease prevention, especially DM, because it is a valuable source of nutrients that are lacking in the Chinese diet, including dietary fiber, resistant starch, B vitamins, vitamin E, selenium, zinc, copper, magnesium, phenolic compounds and so on. It's estimated that 92 million people have diabetes, with another 148 million having pre-diabetes (Yang et al., 2010). DM is certainly motivating the Chinese to promote whole grains, but productivity is another strong motivator. Replacing 50 grams of white rice with the same amount of whole grains and barley would lower risk of T2DM by 16 or 36% (Sun et al., 2010). Brown rice has been associated with lower risk of DM (Zhang et al., 2010). Coarse food grain is potentially beneficial in sustaining blood glucose status and improving insulin sensitivity (Zhao et al., 2011). China will consume about 47 million tons of whole grain foods per year in the future. Sprouted brown rice is a good replacement for polished white rice, it is easily available to increase sprouted brown rice from 3 to 15%; noodles and steamed buns with whole grain foods, and to increase whole wheat flour from 11 to 25% in 2015 (<http://wholegrainscouncil.org/files/BeijingWGFForumOverview.pdf>).

Secondly, functional foods with high resistant starch (RS) for dietary are one of the most important ways of diabetes prevention in China. Resistant starch is starch that escapes from digestion in small intestine and ferments in large intestine, and it is useful for the prevention and treatment of DM, based on decreasing blood glucose and cholesterol as well as triglyceride, to enhance the sensitivity of insulin, and reduce body weight (Wang et al., 2009). The retrograded resistant starch of Gongmi No. 3 is 10 to 13%, that is, it is 55 fold than that of Diantun 502 with aromatic soft-rice ([www.tiankan88.cn](http://www.tiankan88.cn)). RS is effective in improving insulin resistance of T2DM rats (Zhang and Zhang, 2008). Resistant starch can reduce the levels of blood glucose, blood lipid and blood urea nitrogen of type 2 diabetic rats, indicating that resistant starch has the effect of alleviating

diabetic symptoms, and may protect its renal function (Ding et al., 2005). Resistant starch has positive influences on the functioning of the digestive tract, microbial flora, the blood cholesterol level, the glycemic index and assists in the control of DM (Fuentes-Zaragoza et al., 2010), such as Gongmi No.3 with high resistant starch and alkaloids for chronic diseases (diabetes, obesity, hyperlipidemia, intestine diseases and so on) prevention. Consumption of the GM RS-enriched rice meal decreased the postprandial glycemic and insulinemic responses and promoted RS fermentation-related production of H<sub>2</sub> in the large bowel of young and healthy Chinese adults (Li et al., 2010). Compared with uncoated rice and rice mixed with RS4, the RS4-coated rice showed lower starch digestibility, a decreased glucose response and a slower rate of blood glucose decrease (Choi et al., 2010). The glycemic index, glycemic load and insulinemic index values of starchy foods provide important information for the public to manage their diet and could be useful for the prevention of lifestyle-related diseases such as DM (Lin et al., 2010). RS should be effective in improving insulin resistance of T2DM patients (Zhang et al., 2007).

Thirdly, barley for dietary is one way of diabetes prevention in China:

**Barley grain food:** It is better for barley grain to controls blood sugar than that of refined wheat bread or rice (Priebe et al, 2010; Yamanaka-Okumura et al., 2009). They were significantly lower for the peak of glucose and insulin levels after eating barley than those after glucose or oats (Behall et al., 2005). Barley beta-glucan significantly reduces glycemic index of chapatis, particularly at doses of 4 and 8 g per serving (Thondre and Henry, 2009), and consumption of 10 g of beta-glucan significantly reduced peak glucose response at 30 min (Kim et al., 2009). Barley-eaters had significantly lower cholesterol concentration than wheat-eaters, making the modified barley appropriate for obese and diabetic patients (Lifschitz et al., 2002). A well-regulated lifestyle and long-term intake of high dietary fiber (boiled rice with barley) may have beneficial effects on metabolic control in patients with T2DM (Hinata et al., 2007). The eating food naked barley will improve carbohydrate metabolism of healthy adults (Li et al., 2009). Barley is a kind of low-glycemic index food containing  $\beta$ -glucan and plentiful microelements, so it plays an important role in glucose, and lipid metabolism, as well as in preventing and curing DM and its complications (Li and Gao, 2009). Himalaya 292 (a naked barley cultivar) with higher content of soluble and insoluble fiber may be of value in foods designed to assist in the prevention and management of DM (King et al., 2008).

**Barley grass powder:** Supplementation with barley grass powder (BGP) resulted in a significant decrease in fasting blood sugar, glaciated hemoglobin, total cholesterol, low-density lipoprotein cholesterol and non-

high-density lipoprotein cholesterol, and a significant increase in high-density lipoprotein cholesterol levels (Venugopal and Iyer, 2010). The barley seedlings (0.5, 1g/ml) dropped blood glucose significantly on the model of DM induced by alloxan ( $p < 0.01$ ) and the drop rate of blood glucose are 36.76 and 48.89%, respectively (Wang et al., 2006). To eat a small number of barley grass powder every day could effectively improve sleeping, repair memory, enhance immunity, build up their strength, promote wound healing, ease various discomfort reactions, maintain heart and normal blood indicators, enhance detoxification capacity of the body, and slow human ageing process, especially for the population of older, sub-health body, or even with physical health problems (Zhang et al., 2009).

Fourthly, buckwheat for dietary use is one way of diabetes prevention in China. Buckwheat has potential use in the design of foods with lower glycemic index properties (Skrabanja et al., 2001). Tartary buckwheat is attracting increasing interest from food technologists and consumers for its significant health benefits in relieving the DM and so on (Li et al., 2009). Flavones of buckwheat can significantly reduce fasting blood glucose, and improve insulin resistance (Liang et al., 2011). Rutin from buckwheat flowers and leaves could regulate the metabolic disorder of glucose and lipids in diabetic rats, and could improve the insulin resistance, which might be due to the reduction of tumor necrosis factor- $\alpha$  (Li et al., 2010). Fasting blood glucose significantly inhibits renal injury of diabetic rats induced by alloxan, and the mechanism may be related to the inhibition of the formation of advanced glycation end products resulting from lowered blood glucose level (Bai et al., 2010). Tartary buckwheat tea can alleviate the blood sugar level of diabetic rats (Peng et al., 2008). The DM mice test indicates that the buckwheat bread is helpful to restrain DM to certain degree and can reduce blood sugar level (Zhou et al., 2006).

Fifthly, oat and other functional food for dietary use are one way of diabetes prevention in China.

**Oats:** It is especially rich in soluble fiber. In addition to lowering cholesterol levels, soluble fiber-rich diets may reduce the risk of T2DM (Lammert et al., 2008). Dietary supplementation of 6% oat  $\beta$ -glucan concentrate decreased net glucose flux, increased net short-chain fatty acids flux, and decreased peak apparent insulin production, changes that were associated with glucose-dependent insulinotropic polypeptide and glucagon-like peptide-1 mediation (Hooda et al., 2010). Oat  $\beta$ -glucan could effectively decrease blood glucose in diabetic mice (Yan et al., 2011). Oat intake could decrease blood glucose and postprandial insulin significantly in aged patients with type-2 DM (Zhu and Wang, 2008). Oat  $\beta$ -glucan could restore the function of  $\beta$ -cells, and its mechanism was associated with inhibition of p53 gene and enhanced expression of bcl-2 gene (Wang et al., 2006).

Konjak and others: Balsam pear, pumpkin, soybean and taro can help in the control of blood glucose for gestational DM (Pang et al., 2010). Intake of dietary fibers from Konjak can reduce the peak value of blood glucose and 2 h postprandial blood glucose of patients with T2DM and reduces the blood glucose fluctuation after meals (Zhao and Liu, 2009). The levels of blood glucose in all the three soluble dietary fiber treated groups were obviously decreased and the diabetic symptoms such as weight loss, polydipsia and polyphagia were also relieved; the best hypoglycemic effect was found in the high-dose group (1000 mg/kg bw) (Tu et al., 2009). The strong anti-oxidative activity of potato anthocyanins results from the promotion effects of the anthocyanins on the activities of the antioxidant enzymes, and is positively correlated to the anthocyanin content (Zhao et al., 2009).

## CONCLUSIONS AND FUTURE PROSPECTS

Diabetes is becoming a major public health in China. Main reasons of the prevalence of diabetes in China are low dietary fiber, unhealthy life-style and obesity, interaction between genetic and environmental factors. All factors causing DM is summed up in dietary, especially white rice and white flour. There are a lot of loss of elements content and vitamins as well as functional components from brown rice (or whole grains) to white rice (or white flour) especially good rice (flour) for dietary use is a major factors that cause DM. Therefore, functional food for diabetes prevention in China are the functional food with whole grains (brown rice, wheat flour of whole grains, barley, buckwheat, oats and others) and functional white rice with high resistant starch for dietary use.

There are a lot of challenges to promote functional foods with whole grains or high resistant starch in China: China consumed about 50 million tons of whole grain foods per year in the past 50 years, but total diabetes rate was 0.9%; but only consume 1 million tons of whole grain foods now. Yang et al. (2010) reported that DM in China in 2008 affects 9.7% of people over age 20. The barriers of whole grain consumption and high resistant starch products include difficulty with identifying them, dislike for their taste and texture or appearance, a limited availability of whole-grain products in restaurants and schools, as well as the higher cost for some products compared to refined grains. Retailers and health educators can work together to promote improvements in whole grain intake. It is important for restaurants to increase whole grain products, and clearly identify whole grain content. Our goal is to establish one research center of functional foods based on Kuming Tiankang Science and Technology Limited Company with members from the manufacturers, breeding scientists, education, medical and news media, to promote functional foods.

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