



Potential Applications of Cereals and Yams as Functional Foods to Reduce the Risk of Chronic Non-Communicable Diseases

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Authors' contributions

This work was carried out in collaboration among all authors. Authors NNGC, KDPPG and AC designed the review and author NNGC wrote the first draft of the manuscript and managed the analyses of the study. Authors NNGC, KDPPG and AC managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI:10.9734/AJRB/2020/v7i430148

Editor(s):

(1) Dr. Asmaa Fathi Moustafa Hamouda, Jazan University, Saudi Arabia.

Reviewers:

(1) Shah Murtaza Rashid Al Masud, Najran University, Saudi Arabia.

(2) Nalini Tripathi, Vardhman Mahavir Medical College, Safdarjung Hospital, India.

(3) Pragya Ojha, Shri Govindram Seksaria Institute of Technology and Science, India.

Complete Peer review History: <http://www.sdiarticle4.com/review-history/62575>

Review Article

Received 27 August 2020
Accepted 02 November 2020
Published 27 November 2020

ABSTRACT

The chronic non-communicable diseases (NCD) are increasing throughout the populations and the burden of diseases is rising globally. Epidemiological evidences supports claim that intake of foods with certain health benefits and reducing the risk of NCDs are having positive correlation, therefore, a rise in demand for foods including phytochemicals can be observed. Cereals and yams are known to be rich sources of phytochemicals which can be utilized to produce functional food products having the potential of reducing the risk of chronic NCDs such as type 2 diabetes mellitus (T2DM), cardiovascular diseases (CVD) and certain types of cancers. In this review, the potentials of various cereals and yams that are being used as functional food products for human consumption to reduce the risk of NCD are being examined. The study further included a review on different phytochemicals in cereals and yams based functional food products

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and their bioactivity, potential of microencapsulation, cereal by products, influence of starch modification on functional food products, and capability of utilizing cereal by products in functional food industry.

Keywords: Chronic non-communicable disease; functional food; cereal; yam; phytochemicals; bioactivity.

1. INTRODUCTION

The prevalence of chronic non-communicable diseases has become a major issue all over the world. There are four major types of chronic NCDs such as CVD, T2DM, chronic respiratory diseases and cancers which account for more than 71% of all NCD deaths. In detail, CVD, cancers, respiratory diseases and T2DM are responsible for annual deaths of people as 17.9 million, 9.0 million, 3.8 million and 1.6 million respectively [1]. The cluster of risk factors that have been identified as metabolic syndrome include obesity, insulin resistance, hyperglycemia, hypertension, atherogenic dyslipidemia, pro-inflammatory state and prothrombotic state which are leading to progression of CVD [2]. Central obesity has been considered as the major risk factor associated with metabolic syndrome, subsequently increased risk of CVD, T2DM, and certain type of cancers, including colorectal and breast cancer [3].

There are notable life styles factors such as unhealthy diets, physical inactivity, alcoholism and smoking that affection the risk of chronic NCDs. The relation between healthy diet and maintaining or improving health and wellbeing is an established fact from ancient time. However, currently with the life style changes, low preference on the healthy balance diet and physical activity consequently increasing the prevalence of chronic NCDs. Healthy diet provides nutrients for growth and other compounds (secondary metabolites) are also there which can improve human health and wellbeing as functional foods. As a direct definition, a food or a portion of food stuffs which can contribute in disease control other than providing common nutrients are considered as functional foods [4]. Although functional foods are naturally available in all food categories, extraction, characterization and incorporation of bioactive compounds which having functionality on disease preventing into food products is an emerging research area in Food Science and Technology field. Even though all food types such as fruits, vegetables, cereals, legumes and

roots and tuber crops can be utilized in functional food formulation, this review will be narrow down to highlight the application of starchy based cereals and yams in functional foods. They are considered to be as functional foods since providing dietary fibers, bioactive proteins, minerals, vitamins, phytosterols, antioxidants and several other phytochemicals having therapeutic effects such as hypoglycemic, hypocholesterolemic, anti-hypertensive, anti-obesity, anti-microbial, and immunomodulatory activities [5,6]. Other than functional foods, there are emerging technologies such as microencapsulation of probiotics using cereal and yam starches, starch modification, and utilization of cereal and yam byproducts as functional food ingredients. However, the majority of the consumption is limited to a range of cereal and yam varieties. For an example certain varieties of tubers such as potatoes and sweet potatoes and cereal varieties such as wheat, barley, and oat are dominated in consumption and product formulation. Nevertheless, there are several underutilized cereals and yams which are having immense potential as functional foods, limited to some geographical area of the world. Hence, attention should be set on to investigate the underutilized cereal and yam varieties in functional food formulation in order to reduce the risk of chronic NCDs.

2. MEDICINAL PROPERTIES OF CEREALS AND YAMS

The purpose of food consumption has being changing from past to the present time. Previous concern had been on survival, nutrient balance and preventing of adverse effects on health. The current concern is on better health and wellbeing, thus reducing the risk of chronic NCDs such as T2DM, CVD and cancers. Therefore, more attention is on certain foods which promise to provide functional properties. Cereals and yams are starchy foods which can add energy to the diet. Apart from that they contain beneficial phytochemicals which are having therapeutic effects for certain disease conditions. The knowledge of traditional medicine as well as from

the evidences of scientific researches has been revealed the potential of cereals and yams to be a leading character in functional food formulation. Table 1 shows medicinal properties of some cereals and yams varieties and their medicinal properties on reduce the risk of chronic NCDs.

3. BIOACTIVES IN CEREALS AND YAMS AND THEIR HEALTH IMPLICATIONS

3.1 Dietary Fiber

Cereals and yams contain a wide range of dietary fibers significant in improving human health and well-being and prevention of chronic NCDs such as T2DM, CVD and certain types of cancers. Foods that are partially or fully fermented in human large intestine but do not digest or absorb in small intestine are defined as dietary fibers [32]. There are four main categories of dietary fibers in both cereals and

yams namely soluble dietary fiber (SDF), insoluble dietary fiber (IDF), resistant starch (RS) and oligosaccharide.

3.1.1 β -glucan & Arabinoxylan

β -glucan and arabinoxylan both are soluble dietary fibers (SDF) which are significantly present in cereal grains [33]. However, β -glucan is the much knowing SDF in cereals such as barley, wheat and oat and the highest amount of β -glucan (5-11%) are found in barley while wheat and oats having 1% and 3-7% respectively[34]. Health benefits including maintaining postprandial blood glucose level [35], lowering serum cholesterol level [36] and prevention role in colorectal cancer [37] are scientifically proven health effects of β -glucan. Apart from above health benefits arabinoxylan is known to have effect of important in improving immune responses [38].

Table 1. Some varieties of cereals, roots and tuber crops with their medicinal properties

English name	Scientific name	Medicinal properties	Reference
Cereals			
Wheat	<i>Triticum aestivum</i>	Antibacterial, antioxidant, anticancer, antiulcer properties	[7]
Barley	<i>Hordeum vulgare</i>	Weight reduction, reducing blood pressure, blood cholesterol, blood glucose and preventing colon cancer	[8]
Oat	<i>Avena sativa</i>	Reduction of the risk of CVD, T2DM, gastrointestinal disorders and cancer	[9]
Corn	<i>Zea mays</i>	Antioxidant, anti-inflammatory, anti-mutagenic, anti-carcinogenic, and anti-angiogenesis properties	[10]
Rye	<i>Secale cereale</i>	Anti-diabetic, anti-carcinogenic, reduce the risk of CVD	[11]
Sorghum	<i>Sorghum bicolor</i>	Anti-cancer, and reduced chronic inflammation, CVD and oxidative stress	[12]
Sesame	<i>Sesamum indicum, L.</i>	Lowering blood pressure, increase HDL cholesterol, decrease LDL cholesterol levels, reducing T2DM and arthritis	[13]
Millet	<i>Panicum sumatrense</i>	Anti-diabetic, hypolipidemic, antioxidant properties, anti-proliferative, anti-atherogenic, anti-carcinogenic	[14],[15],[16],[17]
Quinoa	<i>Chenopodium quinoa</i>	Anti-diabetic, anti-obesity, reduce risk of CVD	[18]

English name	Scientific name	Medicinal properties	Reference
Flaxseed	<i>Linum usitatissimum L.</i>	Reduce the risk of cancer, T2DM, CVD and cerebrovascular stroke	[19]
Chia seed	<i>Salvia hispanica L.</i>	Balance serum lipid profile, prevent overweight and obesity in diabetes	[20]
Roots and tuber crops			
Purple yam	<i>Dioscorea alata</i>	Prevention and management of osteoporosis and heart diseases, anti – diabetic property	[21]
White yam	<i>Dioscorea rotundata</i>	Anti-diabetic, antioxidant, anti-inflammatory properties	[21]
	<i>Dioscorea spicata</i>	Prevention of heart diseases, anti – diabetic property	[21]
	<i>Dioscorea esculenta</i>	Anti-oxidative, hypoglycemic, hypo-cholesterolemic, antimicrobial, and immunomodulatory activities	[21]
	<i>Dioscorea pentaphylla</i>	Hypoglycemic, antimicrobial, and antioxidant	[5]
Air potato	<i>Dioscorea bulbifera</i>	Anti-diabetic, antioxidant, anti – inflammatory properties	[22]
Taro	<i>Colocasia esculenta L. Schott</i>	Reduces serum cholesterol levels, colon cancer, hypertension, diabetes and the risk of CVD	[23]
Potato	<i>Solanum tuberosum</i>	Decrease postprandial blood glucose level, improve insulin sensitivity, increase satiety, reducing plasma cholesterol level, triglyceride concentrations and fat storage	[24]
Sweet potato	<i>Ipomoea batatas</i>	Anti-oxidative, hepatoprotective, anti-inflammatory, antitumor, anti-diabetic, antimicrobial, anti-obesity, anti-aging properties	[25]
	<i>Asparagus racemosus</i>	Anticancer, anti - inflammatory, antiulcer, antioxidant , Hypoglycemic, antihypertensive activity	[26]
Elephant foot yam	<i>Amorphophallus paeoniifolius</i>	Reducing cholesterol, triglyceride content and blood sugar levels, and promoting intestinal activity and immunity	[27]
Xanthomonassagit ifolium	<i>Morinda officinalis</i>	Hypoglycaemic	[28]
Lotus root	<i>Nelumbo nucifera</i>	Hypoglycaemic, antidiarrhoeal, antimicrobial, diuretic, anti-inflammatory and anti-obesity properties	[29],[30]
Lasia root	<i>Lasia spinosa</i>	Antioxidant, anti-diabetic, anti-hyperlipidemic, anti-bacterial, anti-inflammatory properties	[31]

3.1.2 Inulin

Inulin is a main soluble dietary fiber in yams which has therapeutic role in gastrointestinal illnesses and T2DM, stimulating the immune system while enhancing absorption of certain minerals such as calcium and magnesium [39]. For an example inulin extracted from *Dioscorea esculenta* (lesser yam) was tested for anti-diabetic activity showed significant effect on glycated hemoglobin (HbA1C), creatinine and urea levels of diabetes induced rats [40]. Another animal study revealed the positive effect of inulin on maintaining the blood lipid profile by lowering of triglyceride and cholesterol level [41]. Furthermore, inulin acts as prebiotic substrates for healthy bacteria in gut microflora such as *Bifidobacteria* and *Lactobacilli* thus promotes human health [42].

3.1.3 Resistant starch (RS)

Different types of RS have been identified. Cereal grains contain RS type 1 (physically inaccessible starch) and starch granules of potato like tubers contain RS type II [43]. Sudden fluctuations of the postprandial blood glucose levels due to faster digestion of starches are associated with the T2DM risk [44]. Increasing digestion time after consumption will minimize the rapid fluctuation of postprandial blood glucose level and the risk of T2DM. Results of a study showed RS extended digestion to 5 – 7 hours and reduced the postprandial glucose level, insulin resistance and increase of satiety [43]. Another research has been investigated functionality of RS on blood lipid profile using rat model and showed reduction of plasma cholesterol and triglyceride levels because of the increasing of short-chain fatty acids (SCFA) absorption which was metabolized from RS [45]. Furthermore, RS is a good source of prebiotic for gut microflora and can be used in the process called microencapsulation of probiotics [46]. The prebiotic effect of RS from *Dioscorea alata* L. (purple yam) has been evaluated on the proliferation ability of *Bifidobacterium adolescentis* by *in vitro* assay [47]. In comparison with traditional fibers, RS showed some qualities such as better appearance, texture, and mouth feel together with therapeutic effect which is important in product developments [6].

3.2 Protein

Cereals and yams contain certain types of bioactive peptides and amino acids which can promote human health and wellbeing [48]. The

results of some studies revealed preventive action on cancers of cereal peptides such as lunasin for preventing skin cancers [49] and penta-peptide for preventing colon, breast, lung and liver cancers [50]. Some bioactive proteins of yams such as dioscorin showed immunomodulatory [51], antioxidants [52] and antihypertensive [53] activities.

3.3 Phytosterols

Various types of phytosterols exist in cereals and yams. Cereals contain Campesterol, β-sitosterol, stigmasterol, β-sitostanol, and campestanol as common phytosterols types showing cholesterol lowering and antitumor effect [54] and lignan having a protective effect against cancer [55]. Yams also contain phytosterols such as diosgenin and reported to have a hypocholesterolemic effect [56], cancer chemoprevention [57] and prebiotic potential on lactic acid bacteria [58].

3.4 Polyphenols

Cereals and yams containing polyphenols such as phenolic acids and flavonoids which have several health benefits including antioxidant activity with a greater therapeutic effect on reducing the risk of T2DM, CVD, and colorectal cancer, and risk factors such as blood cholesterol level and hypertension [59,60,61]. Cereal bran is considered as the rich source of phenolic compounds, thus consumption of whole grain is very important. When considering yams, polyphenols are lower in flesh part however there are some tubers like yellow color sweet potato, purple yam that having carotenoids and anthocyanin in flesh part as polyphenols respectively. Table 2 shows bioactive compounds in cereals and yams with recognized functional properties related to reduce the risk of chronic diseases.

4. FUNCTIONAL FOOD

Functional foods are formulated to betterment of human health and wellbeing beyond the fulfillment of common nutrient requirement [80]. There are mainly four categories of functional food products namely fortified, enriched, altered and enhanced products. In detail, fortified products are fortified with additional nutrients such as vitamin and minerals, enriched products are produced by introducing new nutrients or compounds not contain in the particular existing food, in altered products harmful part will be removed, reduced or replaced using beneficial

substance such as fat replacers, and enhanced commodities are naturally enhanced using techniques such as providing special growing conditions, altering feed composition and genetic manipulation [33].

Contribution of cereals in functional food formulation is popular and offer several benefits to the consumer. However, except common cereals such as wheat, oat and barley there are plenty of cereal varieties which could be used in preparation of functional foods. When incorporating cereals or yams into functional foods, whole flour or extractable particular substances can be used. Examples for cereal based functional food products and their functionalities are shown in Table 3.

4.1 β -Glucan as a Functional Food Ingredient

β -glucan is a main SDF in cereals, used commonly in bakery products as a functional

food ingredient. Researches revealed the possibility of adding dietary fibers such as β -glucan into the products to enhance the therapeutic effects using *in vitro* and *in vivo* methods. In a clinical trial, comparison on blood glucose level and insulin response has been done after consuming normal wheat pasta and β -glucan incorporated pasta. The researchers observed a significant reduction of blood glucose level in individuals who consumed β -glucan incorporated pasta [88]. Further, cholesterol lowering effect of oat β -glucan has been evaluated incorporating them into bread, cookie and orange juice and consumed them by mildly hypocholesterolemic individuals. Lowering 6.7% low density lipoprotein (LDL) was observed after consumption of β -glucan incorporated orange juice [89].

4.2 Inulin as a functional food ingredient

Inulin is one of the main types of SDF found in yams. Inulin is used in producing different

Table 2. Bioactive compounds and their functional properties in cereals and yams

Crop	Bioactive compounds	Functional properties	Reference
Black highland barley	Polyphenols	Superoxide radicals scavenging activity, DPPH radical-scavenging activity, and antioxidant ability	[62]
Sprouted barley	Polyphenols	Regulate AMP-activated protein kinase and cholesterol metabolism	[63]
Barley	β glucan	Chemoprevention on carcinogenesis	[64]
Rice, cassava	fiber	Reduce the risk of CVD, obesity and T2DM	[65]
Purple corn			[66]
Black rice	Cyanidin-3-glucoside	Anti-inflammatory property	[67]
Finger millet	Polyphenols	Anti-diabetic property	[68]
Oat	β -glucan	Anticancer property	[69,70]
Rye	Benzoxazinoids	Weight reduction, anti-allergic, anti-inflammatory and anti-carcinogenic effects	[71]
Sorghum bicolor (L.) Moench	Phenolic acid (3-deoxyanthocyanidins)	Anti-cancer effect such as colon, esophagus, liver, breast, and bone marrow	[72]
	Tannin	Inhibit starch digestion by inhibiting enzyme activities	[73]
	Phytosterols	Inhibit the cholesterol absorption	[74]
	Phenolic compounds	Anti-diabetic property	[75]
	α -kafirins	Reduce blood pressure	[76]
Sesame	Lignans (sesamin and sesamol)	Cholesterol-lowering effect and anticancer effect	[13]
			[77]
Sesame	lignin	Antioxidant activity	[13]
Wheat	Lunasin	Anti-cancer property	[49]
Rice	Pentapeptide	Anti-cancer property	[50]
Yam	Dioscorin	Antioxidant, antihypertensive, immunomodulatory,	[78]
	Allantoin	Prevent inflammation and ulcer	[79]

Table 3. Cereal based functional food products

Crop	Main bioactive compounds	Assayed product	Main outcome/s	Reference
Flaxseed	Alpha linolenic acid, lignans and dietary fiber	Cookies	15 % supplementation increased alpha-linolenic acid content, accepted sensorial and rheological characteristics	[81]
		Chappati	Increased total, soluble and insoluble dietary fibers, essential amino acid contents and alpha-linolenic acid content	
Buckwheat	D-chiro-inositol proteins and flavonoids (mainly rutin and quercetin)	Cookies	Reduce fatigue, nasal irritation and headache	[82]
		Honey	Wound healing	
Quinoa	Amino acids, fiber, polyunsaturated fatty acids, vitamins, minerals, saponins, phytosterols, phytoecdysteroids, phenolics, betalains, and glycine betaine	Infant food formulate	Increase plasma levels of IGF-1, increase weight gain, reducing childhood malnutrition	[83]
		Cereal bar	Reduce the levels of triglycerides, cholesterol and LDL, reduce risk of developing CVD.	
Sorghum	Flavones, flavanones and deoxyanthocyanidins	Quinoa flakes	Reduce the levels of triglycerides, cholesterol, LDL and thiobarbituric acid reactive substances	[84]
		Porridge	Increased their total phenolic and flavonoid contents, radical scavenging activities and LDL oxidation inhibitory activity	
Chia seed	Dietary fiber, phytosterols, alpha linolenic acid	Bread, cake, ice cream, burger, etc.,	Increase dietary fiber, alpha linolenic acid, phytosterol contents in the final products	[20]
Barley	β glucan	Bread	Addition of barley middlings upto 30% level increased the fiber and β glucan contents	[85]
Oat	Dietary fiber, β glucan	Pasta	Low GI, quality same as wheat pasta	[9]
Millet	Dehulled oat flour Whole flour	Bread	Antioxidant activity	[86]
		Noodle	Low glycemic index and load	[87]

categories of functional foods since having promising health benefits. Gibson and colleague [90] revealed that inulin is one of the compounds which was proven and most widely examined prebiotic along with highest efficacy [90]. Prebiotic incorporation and symbiosis with beneficial probiotic bacteria is widely used in dairy products such as yogurt. Inulin is also used as a prebiotic in dairy products to boost the growth of beneficial bacteria groups such as *Lactobacillus acidophilus*, *Lactobacillus rhamnosus* and *Bifidobacterium lactis* [91]. Inulin is a scientifically proven an ideal substance which can be used as a fat and sugar replacers for healthy foods such as yogurt

without negatively effect on the consumer acceptability [92]. Hence inulin can be used in non-fat dairy products as a fat replacer and in low sugar products as a sugar replacer [93]. In detail, some researchers have investigated the effect of inulin addition as a fat replacer on physical and sensorial properties of dairy foods such as low fat yogurts [94] and meat products like sausages and showed positive health effects on consumers without compromising the sensory characteristics [95]. Some researches produced sugar-free chocolates [96,97] and custard [98] by replacing inulin as a sugar alternative. Inulin has been incorporated into breakfast cereals and bakery

products and improved some structural attributes of crispiness and freshness of the product [39].

4.3 Resistant Starch as a Functional Food Ingredient

RS are found in both cereal and yam varieties and whole grain or partially milled cereal containing RS type I, while potato like yams containing RS type II [46]. As a definition, RS is type of starch that are not digested and absorbed in the human small intestine and, fermented in the large intestine [99]. Several studies showed RS provide health benefits such as lowering blood glucose level, lowering cholesterol level, cancer preventive action and prebiotic effect [100]. RS has been widely used in production of functional foods and bakery products such as cake, muffins and pasta showed positive effect in sensory and health parameters [101,102]. Characteristics of RS incorporated bread have been evaluated by the American Institute of Baking (AIB) incorporating cellulose, oat fiber, wheat fiber and RS and resulting that bread containing RS have a superior quality with health benefits such as anti-diabetic and hypocholesterolemic compared to those made with traditional fiber [103]. Utilization of RS as nutraceutical ingredients may be useful when developing novel products for consumers with

lower level of caloric and glycemic requirements.

5. CEREALS AND YAMS AS PREBIOTICS

Prebiotics are defined as non-digestible food components that promoting the growth of beneficial colon bacteria and limiting the proliferation of unhealthy bacteria such as *Salmonella* sp. or *Escherichia coli* improving host health. Typically, dietary fibers and oligosaccharides include in prebiotics [104]. In detail, inulin, fructo and galactooligosaccharides, lactulose, and polydextrose have been proven as prebiotics, whereas isomalto-oligosaccharides, xylo-oligosaccharides, and lactitol are categorized as emerging prebiotics [105]. Importantly, cereals and yams contain variety of dietary fibers and oligosaccharides which have been identified as prebiotics. For examples, arabinoxylans consider as main dietary fibers in wheat bran and its hydrolyze product of arabinoxylan oligosaccharides, show a strong prebiotic effect and some tuber crops such as *Dioscorea esculenta* is a major source of fructans/ fructooligosaccharides which considered as popular prebiotic[106]. Potential of cereals and yams as prebiotic substrates to improve the availability and functionality of probiotic bacteria in functional food products is shown in Table 4.

Table 4. Cereals and yams as prebiotics in probiotic functional food products

Crop/s	Probiotic culture/s	Product	Main outcome/s	Reference
White and red sorghum, pearl millet and wheat	<i>Pichiakudriavzevii</i> (yeast culture)	Cereal based fermented product	Counts of yeast cells between 7.46 and 8.22 Log ¹⁰ cfu/mL within 24 h, Scavenged DPPH from 200 µmol/L methanolic solution by 55.71%	[107]
Pearl millet	<i>Weisella confuse</i> , <i>Lactobacillus fermentum</i> , <i>Lact. salivarius</i> and <i>Pediococcus spp.</i>	Porridge	Occurred in levels of 10 ⁸ CFU ml) ¹ in fresh drink, antimicrobial activity and acid and bile tolerance	[108]
Elephant foot yam	Lactobacilli	UHT milk	Glucomannan in elephant foot yam significantly increased the number of cfu in the UHT milk when compared to inulin	[109]
Yacon root			As prebiotic oligosaccharide	[110]
Chinese yam	<i>Lactobacillus murinus</i> and <i>Lactobacillus reuteri</i>		Diosgenin, a steroidal sapogenin enhanced the growth of <i>Lactobacillus murinus</i> and <i>Lactobacillus reuteri</i> , and inhibit the growth of <i>enterococci</i>	[111]

6. MICROENCAPSULATION OF PROBIOTICS

To get health benefits there are certain limitations, which required from a probiotic food. They are 10^6 CFU/g probiotics should be in the product or at the point of delivery there should be 10^7 CFU/g of probiotics in the product or to achieve 10^8 CFU/g of daily intake, sufficient amount should be eaten [112]. However it is not possible to maintain that recommended levels since incorporated probiotic content may be reduced specially in between the processing steps. Microencapsulation of probiotic bacteria is a novel technology which can protect the probiotic cells from degradation by the undesirable environment conditions such as temperature and acidity and release cells back at controlled rates at the friendly conditions [113]. Normally, Alginate, a polysaccharide derived from brown seaweed is used as the encapsulation medium [112,114]. Encapsulation of probiotic strains using plant protein including cereal fractions as wall material of the capsule has been revealed and several encapsulation techniques have been investigated to enhance the viable probiotic bacteria counts in functional foods. Further, high amylose maize starch granules have been used as a delivery system for probiotics and the survivability was tested using *in vitro* and *in vivo* methods. Results showed that the enhancing of probiotic survivability after undergoing both types of tests [115]. Since, utilizing cereal and yam prebiotics in microencapsulation has not been fully established and further extended studies are required with different crop varieties along with the modified techniques.

7. MODIFIED STARCH FROM CEREALS AND YAMS

Cereals and yams both are starchy based foods and starch is a main raw material in wide variety of food products. However, native starch shows some undesirable characteristics which are limiting the processability. Therefore, to meet the demanding requirements of the food industry the undesirable properties in native starch should be altered. The technology of altering the native starch is named as starch modification which promising to correct technical shortcomings facing during food processing. Apart from that, these modified starches have potential to engage in functional food formulation since they can act as fat and sugar replacers. Malta dextrin is a hydrolyzed product from plant starches such as

corn, wheat, rice and potato which widely used as a popular fat replacer in low fat mayonnaise, margarine, low fat butter spread, and low fat ice cream [45]. Tapioca is another modified starch extracted from cassava and has been used as a fat replacer in low fat cheese [116]. Another dairy product; low fat yogurt has been processed incorporating fermented modified potato starch [117]. Other than being a fat replacer modified starches can be used as texture improver in bakery products such as bread [118].

8. CEREAL BY-PRODUCTS

Cereal by-products originate from dry milling, wet milling, and brewing of cereal grains. The nature of the by-products is changed according to the cereal variety and the process conditions. These grain fractions are rich in bioactive compounds such as fiber, minerals, vitamins, lignans, phytosterols, and phenolic compounds. Therefore the wastage obtained during the milling process is a good source of bioactive compounds which can be incorporated into foods to get health benefits for human apart from being as animal feed. Rice is a staple food in several Asian countries and milling process is done to satisfy the consumer preference. Albeit, rice bran is rich in phytosterols and micronutrients such as vitamin E and oryzanols which having positive effect on maintaining the blood lipid profile, reduce the risk of CVD and certain cancers [119]. Wheat bran contains non-starch polysaccharides, starch, protein, lignin and phenolic compounds such as ferullic acid, vanillic acid, p-hydroxybenzaldehyde, p-hydroxybenzoic acid, and trans-coumaric acid [120]. Wheat bran is incorporated as composite flour in bread, muffins, and cookies to increase their dietary fiber content [121]. Considering the beneficial therapeutic effects of bioactive compounds in cereal industry waste, mechanisms should be developed to utilize them not only in a conventional way such as animal feed but also as functional food ingredients to formulate novel functional food products or increase the healthy value of existing products for human consumption.

9. CONCLUSION

The purpose of this review was to study about the potential applications of cereals and yams as functional foods to reduce the risk of chronic NCDs. Cereals and yams are important components of human diet and provide a range of essential nutrients. They can be easily grown

and adapted to harsh situations in the environment. Both cereals and yams contain different categories of phytochemicals such as bioactive proteins, polyphenols, phytosterols, vitamins, minerals, resistant starch and dietary fibers which were proven to be providing functional properties in addition to the main role as an energy provider. These phytochemical components have been linked to therapeutic effects such as anti-oxidative, hypoglycemic, hypocholesterolemic, anti-cancer, antimicrobial, and immunomodulatory activities and known to reduce the risk of major chronic NCDs. Cereal and yam based products are prepared in different ways in all over the world. Investigation of new functional ingredients will give an advantage to the food processors that can add extra value to the products. Thus, studying on novel bioactive compounds of commonly used cereals and yams as well as unconventional varieties is a timely action. Utilization of RS and dietary fiber based on cereals and yams as nutraceutical ingredients may be useful when developing novel food products for consumers with lower level of caloric and glycemic requirements. The prebiotic efficacy of cereals and yams can be utilized in the novel technique of microencapsulation, which can enhance the viability of probiotic bacteria cells in the final product. Although cereals and yams are a widely used starchy based food crops in food industry, some undesirable characters are limiting the processability of food products. Starch modification is one of the techniques to minimize the difficulties occurred in food processing and need to be apply more in order to improve the qualities of food products. Mechanisms should be developed to formulate novel functional food products or increase the healthy value of existing products utilizing cereal by products in order to gain ultimate utilization of bioactive compounds in cereal industry waste. Since, food security is identified as a global issue, promoting novel processes for utilizing cereals and yams and by products of them may be very important as a contribution to the food and nutrition sector.

ACKNOWLEDGEMENTS

We greatly acknowledge the financial support provided by World Bank AHEAD project under the research grant AHEAD/RA3/DOR/WUSL/FST.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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