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Coconut meal: Nutraceutical importance and food industry application

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Abstract: In tropical regions coconut is the tree of great significance: it provides millions of people with food, employment, and business opportunities. The fruit is referred to as 'miracle fruit' due to its inherent rich profile of macro- and micro-nutrients for human nutrition and health. Different products, such as coconut water, milk, raw kernels, oil and desiccated coconut are commercially processed. Coconut flour is a byproduct of coconut milk and oil industry which is made from coconut meal leftover after processing. Being a rich source of dietary fibre and protein, it has found numerous applications in different functional foods. Coconut flour can be successfully incorporated into various food products, such as bakery, extruded products, snacks, and sweets. It has antidiabetic and anticancer effects, prevents cardiovascular diseases, and improves immune function. Coconut flour is also gluten-free and its nutritional composition is quite comparable to that of wheat flour. Gluten-free food products enriched with coconut flour are a healthy and viable option for the people with celiac disease. In this paper, we summarised the present use of coconut flour. There is an apparent need to convert the food processing byproducts into functional ingredients in order to implement their environment-friendly and efficient utilisation.

Statement of Novelty: The review discusses the recent research of coconut meal valorisation with the focus on technologies allowing the promotion of coconut meal and its commercial availability.

Keywords: Coconut flour, dietary fibres, celiac disease, functional food, anticancer, antidiabetic, pasta, bakery

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INTRODUCTION

Coconut (*Cocos nucifera* L.) palm is a monocotyledon belonging to *Arecaceae* or *Palmae* family. Coconut is among the ten most useful trees in the world and is referred to as 'tree of life', 'tree of heaven', 'tree of abundance' due to its multi-utilisation in nutrition, medicine, cosmetics, etc. [1]. Coconut palm can be processed into coconut water, coconut milk, coconut sugar, coconut oil, and coconut meat. Coconut consists of outer fibrous coat, or husk known as exocarp, and inner hard protective endocarp, or shell. A white albuminous part is endosperm, or coconut meat, and inner cavity is filled with clear fluid called coconut water (Fig 1).

There are two main varieties of coconut, i.e. tall and dwarf ones, depending on fruiting time. The tall varieties

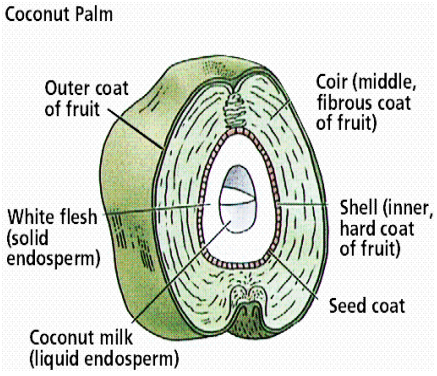

Figure 1 Internal view of Coconut [2]

grow slowly, and their fruiting occurs after 6–10 years of plantation. The dwarf varieties grow faster, and fruiting occurs within 4–5 years of plantation [3]. Indonesia, Philippine and India are the largest coconut producers in the world, with the annual production of 61, 18 and 15.86 million tons, respectively [4]. In India, Kerala's coconut production is 48.79%, followed by Karnataka (18.90%), Tamil Nadu (17.70%), and Andhra Pradesh (5.50%), which together accounts for 91% of the total production in the country [5].

Virgin coconut oil (VCO) is the main product from the coconut industry of great economic importance. VCO is extracted from the fresh, mature coconut kernel mechanically with or without the use of heat. Refining, bleaching or deodorising is avoided in VCO extraction to retain all its natural properties. The white residue, or meal, left after the extraction of VCO is called Virgin Coconut Meal (VCM). It can be milled to obtain flour rich in dietary fibre and considered as a suitable ingredient in the formulation of functional foods. Production of coconut flour has been increased recently due to its functional properties such as prevention of diseases like diabetes, cardiovascular diseases, and colon cancer. Waste generated in the fruit, vegetable and nut industry is full of valuable nutrients and needs to be reused in value added food products thus providing additional economic benefits [6, 7].

RESULTS AND DISCUSSION

Processing of coconut flour. De-oiled cakes of coconut and flour are a good source of dietary fibres. Being a rich source of dietary fibre and protein, it has found numerous applications in different functional foods. Non-starch polysaccharides (NSP) or dietary fibre are protective against gastrointestinal cancer, including esophageal one [8].

There are two methods for VCO extraction: dry and wet ones. In dry processing the fresh mature coconuts are dehusked and deshelled. After the removal of brown coat, the coconuts are grated and dried at 65–70°C in tray or vacuum drier. The dried coconuts are then subjected to cold press expeller to extract coconut oil. The white low fat residue/meal obtained is grinded to make coconut flour. In wet processing, the coconut milk is extracted from the fresh kernel which is then fermented naturally (at 35–40°C for 16–24 h) to obtain VCO from coconut curd by phase separation. The meal is milled into coconut flour [9]. The solvent extraction method is generally avoided because of health hazards and low quality meal [10]. Normally, the meal or the residue obtained after the extraction of coconut oil is used as cattle and poultry feed. Nevertheless, coconut meal has nutraceutical properties, which make it useful for human consumption, and should be incorporated in various food products [11]. The meal contains carbohydrates, protein and dietary fibre, which can also be utilised for food enrichment. In addition, another advantage of the meal is its low cost.

During food production and processing, hygiene and sanitation are prerequisites to avoid any hazards to enter in food supply chain [12]. The main concern in food utilisation is that the unhygienic processing makes copra press cake unsuitable for consumption by humans. However, in order to overcome this problem, coconut meal obtained from virgin coconut oil extraction can be processed into coconut flour [13]. Coconut flour can be marketed to the bakery, snacks, and noodles manufacturers [14]. There is an apparent need to convert the food processing by-products into functional ingredients in order to implement environment-friendly and efficient utilisation of these by-products.

Nutritional composition of coconut flour. Composition of coconut flour mainly depends upon the method employed for the extraction of coconut oil. However, varieties have slight influence on oil content of coconut and, thus, on flour. According to [15], coconut flour is quite superior to wheat flour in terms of protein, fibre, mineral, and lipid profile (Table 1).

Khan *et al.* investigated coconut flour composition made from coconut meal obtained by dry processing method [16]. The reported composition was: moisture, 6.7%; ash, 1.55%; protein, 14.3%; fat, 54.0%; fibre, 20.50%; and carbohydrates, 23.40%. Igbabul *et al.* investigated the composition of coconut flour obtained from fermented coconut slices which were deoiled by dry processing method [17]. Thus, obtained coconut flour possesses moisture of 5.27%; ash, 2.76%; protein, 12.31%; fat, 0.48%; fibre, 11.81%; and carbohydrates, 67.37%. Gunathilake *et al.* investigated the dry processed coconut flour composition as: moisture, 9.76%; ash, 0.51%; protein, 9.90%; fat, 0.87%; fibre, 0.50%; and carbohydrates, 78.46% [18]. Coconut flour produced by dry processing is rich in protein, while flour from wet processing is predominantly rich in fibre content.

Health benefits of coconut flour. Functional food is any food that imparts a positive effect on people's health and provides basic nutrition. Coconut milk residue and virgin coconut oil meal are rich sources of dietary fibre [19]. Dietary fibre is the best ingredient to be used in the development of functional foods, due to its health promoting effects, such as controlling cholesterol and blood sugar levels, increasing the fecal bulk volume, proliferation of gut microflora, decreasing intestinal

Table 1 Comparative proximate composition of wheat flour and coconut flour

Component	Wheat flour, %	Coconut flour, %
Moisture	9.76	4.20
Ash	0.51	5.96
Protein	9.90	21.65
Fibre	0.50	10.45
Fat	0.87	8.42
Carbohydrates	78.46	59.77

Table 2 Health benefits of coconut flour

Component	Health benefit	Biological action	Reference
Fiber	Antidiabetic effect	Reduces postprandial glucose levels	[20]
	Cardiovascular disease prevention	Lowers the serum cholesterol, triglycerides, and LDL cholesterol levels	[23]
	Prebiotic and immune modulator	Oligosaccharides produced by enzymatic hydrolysis of polysaccharides present in coconut meal are a potent prebiotic substance for humans	[33]
	Weight control	Gives bulkiness without supplying fats, resulting in consumption of less food and low calories	[36]
Fat	Cardiovascular diseases prevention	Coconut fats elevate the levels of high density lipoprotein (HDL) cholesterol, a good cholesterol known to lower the risk of coronary heart disease	[25]
Protein	Hypolipidemic effect	Arginine checks hypercholesterolemia by correcting the reduced concentrations of EDRF	[26]
Phenols and flavonoids	Anticancer effect	Coconut flour extracts affect the integrity of the Caco-2 cancer cells due to release of lactate dehydrogenase as found in the cytotoxicity assays	[28]

transit time, trapping carcinogenic agents, etc. Fibre can be supplemented using coconut flour to develop healthy foods low in calories and fats. Coconut flour is a potent functional ingredient used in food products with wide health benefits (Table 2).

Antidiabetic effect. Glycemic index (GI) is a therapeutic principle for diabetes mellitus. GI can be estimated by determining the increase in blood glucose concentration after the intake of a test meal for a specific period of time and compared to equivalent control meal consisting of bread or glucose. Low glycemic index food reduces the postprandial blood glucose levels. The glycemic index of coconut flour supplemented foods decreases with increase in the amount of coconut flour due to its high fibre content. This forms a scientific basis for its utilisation as a functional food for the dietary control and management of diabetes mellitus [20].

Not only the coconut dietary fibre but also the coconut kernel proteins have an antidiabetic effect. Coconut is rich in L-arginine which contributes to glucose homeostasis through nitric oxide synthase pathway leading to pancreatic beta cell regeneration [21]. It regulates blood glucose levels and improves insulin sensitivity in diabetic and non-diabetic individuals [22].

Cardiovascular diseases prevention. An increase in fibre intake is beneficial for heart health as it lowers blood pressure and serum cholesterol levels thus reducing the risk of stroke and hypertension. Coconut fire was shown to lower the serum cholesterol, triglycerides and LDL cholesterol levels thus reducing the risk of coronary heart diseases. After fat digestion, bile acids are reabsorbed in the body and then converted into cholesterol. Coconut fibres prevent the re-absorption of bile acids into enterohepatic circulation and bile acid are excreted through feces along with fibre. This justifies the need for the development of coconut flour food products as a functional food [23].

The short chain fatty acids (butyrate, acetate and propionate) produced by the fermentation of dietary fibres in large intestine inhibits the synthesis of cholesterol in the liver. Propionate is known to inhibit HMG (3-hydroxy-3-methylglutaryl) CoA synthase, a limiting enzyme for the synthesis of cholesterol from acetyl- CoA in the liver. This fermentation metabolite decreases the cholesterol synthesis by the rate of 45% [24].

Coconut fats increase the level of high density lipoprotein (HDL) cholesterol, a good cholesterol lowering the risk of coronary heart disease. Although the polyphenol content in coconut is high, it maintains normal levels of lipids in tissues by trapping the reactive oxygen species in plasma and interstitial fluid of the arterial wall resulting in the inhibition of LDL oxidation, reversal of cholesterol transport and reduction in the intestinal absorption of cholesterol [25].

Coconut proteins also exhibit hypolipidemic effect due to the high content of L-arginine (24.5%), a precursor of nitric oxide [26]. Nitric oxide is an endogenous vasodilator and also prevents the aggregation and adhesion of platelets and was identified as an endothelium derived relaxing factor (EDRF). The consumption of dietary arginine checks hypercholesterolemia by correcting the reduced concentrations of EDRF [27]. Consumption of coconut products, such as desiccated coconut and coconut flour, can therefore help improve the lipid profiles.

Anticancer effect. Colorective cancer is the cancer of digestive tract, which depends on genetic factors (over expression of enzyme cyclo-oxygenase-2), oxidative stress and diet. Antioxidants are free radical scavengers and are considered as the potent chemo-preventive components. Coconut flour contains high content of phenols and flavonoids, which have antioxidant properties (Table 1).

The study reported that coconut flour extracts affect the integrity of the Caco-2 cancer cells of the colon due to release of lactate dehydrogenase as found in the cytotoxicity assays. The extracts also increase the activity of detoxifying enzyme catalase which is responsible for the neutralisation of hydrogen peroxide [28]. Butyrate produced during the intestinal fermentation of fibres has anti-inflammatory and anticarcinogenic properties [29]. It enhances cell

Table 3 Coconut flour food products

Food product	Ingredients used	References
Bread	Refined wheat flour, coconut flour (10–30% substitution with refined wheat flour)	[18]
Plain cake	Wheat flour, coconut flour (10–30% substitution with wheat flour), egg, sugar, powder milk, baking powder and soybean oil	[41]
Cookies	Wheat flour, coconut flour fiber concentrate (10% and 20% substitution with wheat flour), sugar, fat, corn flour, salt, ammonium carbonate, sodium bicarbonate and water	[19]
Extruded ready-to-eat (RTE) snacks	VCM flour (5–20% substitution with rice flour), rice flour, sugar and cardamom powder	[16]
Cold extruded and baked RTE snacks	African breadfruit flour, cashew nut flour, defatted coconut flour (in the ratio of 8:5:2 respectively), sugar, water, salt, flavourings and wheat flour	[46]
Gluten free cookies	Rice flour, coconut flour (30% and 50% substitution with rice flour), maple syrup, butter, egg powder, ammonium bicarbonate and sodium bicarbonate	[44]
RTE Breakfast cereals	Maize flour, African yam bean seeds flour, coconut flour (10–50% incorporation in maize and African yam bean flour blends), sorghum malt extract, sugar, salt and water	[50]
Noodles	Wheat flour, coconut flour (10–30% level incorporation in wheat flour), water and salt	[15]
Biscuits	Refined wheat flour, virgin coconut meal (5–25% replacement with refined wheat flour), hydrogenated fat, sugar, baking powder and water.	[43]
Breakfast cereal	Composite flour (rice flour and soybean flour in the ratio of 50:50), coconut flour (5–20% replacement with composite flour)	[51]
Gluten free cookies	Rice cream, coconut flour, potato starch, sugar, butter, eggs, xanthum gum, salt, sodium carbonate, lemon juice, honey essence and chocolate chips	[48]
Sweet meat (ladoo)	VCM, desiccated coconut powder, whole wheat flour, sugar, cashew nut and hydrogenated fat	[53]

differentiation which prevents tumor formation in colon. Excess bile acids induces oxidative stress by the production of reactive oxygen species which causes repeated DNA damage leading to mutations and carcinogenesis in the gastrointestinal tract [30]. The secondary bile acids contribute to the risk of colorectal cancer. Dietary fibre binds with the bile acids and facilitates their effective fecal excretion [31].

Bioactive peptides also possess antioxidant properties and other health benefits. The two peptides from the coconut cake protein isolates, Pro-Gln-Phe-Tyr-Trp and Arg-Pro-Glu-Ile-Val, are the peptides exhibiting free radical scavenging activities with 4.28 and 7.65 µg/mL IC50 value respectively (IC50 is the concentration of the peptide needed to scavenge 50 percent of the radical activity) [32].

Prebiotic and immune modulator. Dietary fibres act as prebiotics and are essential for intestinal microflora. Oligosaccharides produced by enzymatic hydrolysis of polysaccharides present in coconut meal are a potent prebiotic substance for humans [33]. Prebiotics are the non-digestible oligosaccharides favouring the growth of *Bifidobacteria*, *Lactobacilli* and other microorganisms responsible for the intestinal immune responses [34]. These bacteria carry out the fermentation of the prebiotic oligosaccharides and produce short chain fatty acids. *ß*-1,4-Mannobiose is a disaccharide obtained from coconut flour which exhibits immune modulating and prebiotic effect. It increases the production of antibody IgA which prevents the growth of pathogenic bacteria by increasing the phagocytic activity. The branched structure of *ß*-1,4-Mannobiose shows similarity with the bacterial cell wall components and thus acts as a toll-like receptor agonist. Toll-like receptors activate the signaling pathways that are responsible for the host defense mechanisms [35].

Weight control. Dietary fibre is an important tool for obesity control by the nutrition and diet professionals. Consumption of dietary fibre is known to show significant changes in the gut hormones, glycemic index, gastric emptying, and satiation indices. As coconut consists of fibre, it absorbs water and provides a feeling of fullness. It gives bulkiness without supplying fats, resulting in consumption of less food and low calories and thus regulating weight. Hypoenergetic diet, when supplemented with coconut flour, lowers glucose and cholesterol levels thus managing obesity [36].

Gluten free flour. Celiac disease is genetically inherited chronic disease characterised by an immune response on the consumption of gluten. This auto immune response causes villi damage of the small intestine and thus hampers the absorption of nutrients into the body leading to gastrointestinal distress and malnutrition [37]. At present, the only treatment for gluten intolerance is strict avoidance of gluten containing foods made up of wheat, barley, and rye. The main constraint in gluten free diets is that these are quite poor in dietary fibres and carbohydrates.

On the contrary, coconut flour contains abundant amount of fibres (Table 1). Gluten free foods can be enriched with natural non-cereal gluten free fibre sources such as vegetables, fruits, nuts, legumes, or seed. Coconut flour is marketed as a gluten free product for flour replacement and as an additive to cereal products (Table 3). Thus, gluten free food products enriched with coconut flour are a healthy and viable option for the people with celiac disease.

Antinutrients. Anti-nutrients are the substances which either inhibit the absorption of nutrients or hinder in their further metabolic pathways. Major substrate cereals, legumes and millets have certain antinutrients, such as phytic acid, lathyrogens, saponins, lectins, haemagglutinins, alpha amylase inhibitors, etc. They lower the bioavailability of minerals and inhibit the protein digestion. Coconut flour can be considered as a good substitute for gluten free products and other processed due to the absence of an antinutritional factor [38].

Coconut flour. Coconut flour is successfully incorporated into bakery, extruded products and traditional sweets.

Bakery products. Cereal based cookies, bread, crackers (an integral part of human diet) accounts mainly for energy source in human nutrition therefore they are good vehicles for supplementation of nutrients [39]. Gunathilake *et al.* used coconut flour in different proportions (10, 20, and 30%) for refined wheat flour bread to enhance proteins, amino acid profile and dietary fibres [18]. Cereal proteins are not a valuable source of lysine [40]. The mixing behavior of the wheat flour and coconut flour blends was analysed. It was found that water absorption decreased while dough development time, arrival time, and stability increased with 20% substitution. The study concluded that acceptable quality of bread can be made by 20% substitution of the wheat flour with coconut flour.

Hossain *et al.* made nutritionally rich cake by incorporating coconut flour in wheat flour [41]. Substitution of wheat flour with 20% coconut flour for the preparation of plain cake resulted in increase in moisture by 0.75%, protein by 0.58%, fat by13.84%, ash by 0.91%, crude fibre by 0.9%, while the carbohydrate content decreased by 16.16%. The moisture content increased due to the presence of water holding matrix i.e. dietary fibres (cellulose, hemicelluloses, lignin, etc.), which resulted in an enhancement of cake volume.

Yalegama and Chavan made fibre supplemented cookies with coconut flour fibre extracts [13]. Fats, proteins and sugars were removed from coconut flour and the purified fiber was incorporated into cookies. 10% coconut fibre substituted cookies showed good overall acceptability. The coconut flour was found to contain 13.4 g/100g fat, 9.3 g/100g crude fibre, 3.7 g/100g moisture, and 18.8 g/100g total sugars. Cell wall polysaccharide concentrate was prepared from the coconut flour with free flowing properties and was used in the preparation of cookies. The cookies showed a slight increase in moisture content by 1% and ash content by 0.19%. The protein content decreased by 0.1% and carbohydrate increased by 3.2%. The protein content decreased and carbohydrate increased due to addition of extra sugar and fat in the cookies. The sensory properties decreased with increasing level of substitution with coconut fibre. High fibre cookies can be made by supplementation with coconut fibre.

Sivakami and Sarojini formulated biscuits using defatted coconut flour, rice flakes, and defatted soya flour [42]. The biscuits contained lower amount of fibre (2 g) which might be due to highly processed flours used for the preparation of biscuits. The carbohydrate content of biscuits was found to be in the range of 54–57 g. The biscuits provided 464 kcal of energy per 100 g.

Srivastava *et al.* prepared virgin coconut meal (VCM) incorporated refined wheat flour biscuits [43]. Sample investigations showed that incorporation of 15% VCM was most suitable for the acceptable sensory qualities of biscuits. Fibre and protein content was comparatively high as compared to the 100% wheat flour biscuits. Addition of VCM increased the hardness of the dough and decreased the adhesiveness. Addition of VCM also resulted in an increase of moisture by 1.14% (due to high water absorption capacity), fat by 14.55%, protein by 1.41%, ash content by 0.47%, and fibre by 3.40%. The 5–25% VCM resulted in decrease in palmitic and oleic acids, while lauric, myristic, caprylic and capric acids increased. Potassium content increased by 382.82 mg/100 g, calcium by 14.8 mg/100 g, iron by 4.94 mg/100 g, sodium by 32.98 mg/100 g, and zinc by 0.51 mg/100 g. The hardness of dough increased by 2.41 N on 10% replacement with VCM. Coconut meal flour is used owing to its high energy density, high food grade proteins, functional properties and other health benefits. The study found that de-oiled coconut meal flour biscuits were rich in all nutrients and can be used for the production of supplementary protein foods.

Paucean *et al.* developed gluten-free cookies from rice and coconut flour blends with pleasant flavour and taste [44]. The nutritional properties of coconut flour make it suitable for the value addition of the baked foods. 50% substitution of coconut flour with rice flour was most acceptable in sensory qualities and showed increase in moisture by 6.65%, total fat by 2.15%, proteins by 2.55% and ash by 0.38%.

Snacks. Modern lifestyle improved living standard, and changing eating habits have opened a huge market of snacks [45]. Khan *et al.* made virgin coconut meal (VCM) incorporated rice based extruded ready-to-eat snacks [16]. The extrusion temperature was maintained from 40 to 185°C for 9 zones with screw speed of 150 rpm. Incorporation of VCM in the amount of 10% in rice snacks was most acceptable. It showed a decrease in expansion ratio by 0.233, mass flow rate by 16 g/min while increase in bulk density by 0.36 g/ml, water holding capacity by 1.83 g/g, fibre content by 0.21%, and protein by 0.77%.

Okafor and Ugwu made cold extruded and baked RTE snacks from blends of breadfruit (*Treculia Africana* L.), cashewnut (*Anacardium occidentale* L.) and coconut meal [46]. Coconut flour addition showed an increase in fibre by 0.47%, fat by 1.16%, bulk density by 0.06%, pro vitamin by 2.6 mg/100g, vitamin B_2 by 0.046mg/100g, vitamin B_3 by 0.116 mg/100g while decrease in moisture

by 1.75%, protein by 1.32%, carbohydrates by 3.87%, porosity by 0.04% and lateral expansion by 2.33%. The fibre content of the extruded snacks increased with the addition of defatted coconut flour. As was proved, fibre rich foods control the blood glucose levels in diabetic people; therefore the snacks with coconut flour as one of the ingredients have potential application as diabetic food.

Mihiranie *et al.* made snack crackers with coconut flour to improve the dietary fiber, protein and mineral content [47]. Addition of coconut flour decreases the thickness and puffiness of the crackers. 20% of the defatted coconut flour can be successfully added to the wheat flour without compromising the sensory properties. It was concluded that defatted coconut flour is a potent ingredient for the formulation of healthy and low cost snack crackers.

Queiroz *et al.* prepared potato starch gluten free cookies with 10% incorporation of coconut flour [48]. This amount of coconut flour resulted in an increase in moisture by 10.5%, ash by 0.12%, protein by 1.08%, lipid by 3.46%, as well as in a decrease in carbohydrates by 15.19% and energy value by 25.1 kcal/g. The enrichment of the cookies with coconut flour improved its nutritional quality and provided superior physical and physicochemical properties to the product. The lipid and protein content was increased but the carbohydrate content was decreased.

Breakfast cereal. Ready-to-eat breakfast cereals are gaining popularity due to convenience and improved nutritional value [49]. Okafor and Usman prepared RTE breakfast cereals from blends of maize, African yam bean, defatted coconut cake and sorghum malt extract [50]. It was concluded that addition of defatted coconut flour increased the pH and water absorbing capacity of the formulation but decreased the bulk density, oil absorbing capacity and viscosity of the breakfast cereal. Increased levels of coconut flour addition showed more protein digestion. 50% substitution of coconut flour resulted in an increase in water absorbing capacity by 8.07%, in vitro protein digestibility by 15.9% and in a decrease in oil absorption capacity by 0.45%, foam capacity by 1.01%, viscosity by 11.35%, and emulsification capacity by 1.64%.

Ojali *et al.* made breakfast cereals by blending rice, soybean, and defatted coconut flour blends [51]. It was found that the protein and crude fibre content increased with the addition of soybean and defatted coconut flour, respectively, while the carbohydrate content decreased. Thus, the nutritional quality of the breakfast cereals can be enhanced by addition of soybean and defatted coconut flour. 20% coconut flour composition resulted in an increase in ash by 1%, crude fibre by 0.54%, carbohydrate by 1.76%, crude fat by 0.7% and a decrease in crude protein by 6.72%, tannin content by 0.27%, and oxalate content by 1%.

Pasta. Pasta is the primary convenience food available in different shapes and size like spaghetti, noodles, vermicelli, etc., which are consumed worldwide [52]. The nutritional and functional characteristics of noodles can be increased by their fortification with proteins and fibres. Noodle fortification can be an effective public health intervention. Gunathilake and Abeyrathne developed coconut flour incorporated wheat flour noodles to supplement wheat flour noodles with fibre and protein [15]. Wheat flour noodles were used as a medium for the incorporation of fibre and protein because in Asia 40% of the wheat flour is used for making noodles. The noodles made by addition of 20% coconut flour were not much different from 100% wheat flour noodles in sensory properties. 20% substitution showed more stable dough due to stabilisation of gluten by coconut proteins and thus better textural properties.

Sweets. Coconut burfi enjoys great popularity, especially in Southern India. It is generally made from desiccated coconut. Coconut ladoo is also a popular Indian sweet rich in fibre and protein. It generally contains sugar, wheat flour, hydrogenated fat, dry fruits and flavouring substances in desiccated coconut powder [11]. Srivastava *et al.* made Indian traditional Sweet meat (ladoo) from VCM and analysed the shelf life of the product under different conditions at the ambient temperatures of 15–35°C [11]. The main ingredients used in the formulation were VCM, sugar, and water.

The study found that the samples with potassium sorbate, an antimycotic agent, showed a shelf life of 4 months as compared to the samples without it, whose shelf life was only three weeks due to mold growth and fermenting odour. The loss of moisture from the samples and sorbic acid degradation rates were higher in polypropylene packaging as compared to the metalised polyester packaging.

Normally, coconut ladoo is made from desiccated coconut and sold by the small scale confectioners without proper protective packaging material. The study found that during storage the samples packaged in polypropylene turned hard and brittle because of the moisture loss, while the samples packaged in metalised polyester remained soft longer.

Awasthi made gluten-free coconut flour ladoo and coconut flour burfi [53]. Coconut flour is a useful product for gluten-allergic people because it is gluten-free. It can be used as a wheat flour substitute for preparing various dishes. Fat and protein contents in ladoo were 33.8% and 2.1%, respectively, while those in burfi were 46.6% and 2.91%. Table 3 shows coconut flour incorporated to food products.

CONCLUSION

Coconut meal obtained from extraction of virgin coconut oil can be used in the form of coconut flour as it is nutritious and a good source of proteins, minerals and dietary fibre. Coconut flour made from coconut meal promotes health and prevents diseases such as diabetes, obesity, colon cancer, and cardiovascular diseases. The flour can be used in the preparation of gluten-free products for individuals with celiac disease.

Utilisation of coconut meal in the form of coconut flour aims at incorporation of dietary fibres and proteins

into the gluten free food. In India, the meal obtained after the extraction of coconut oil is usually discarded or used as animal feed. If hygienically processed, the meal can be used to make flour, which can be utilised for making a variety of food products. Agro-industrial waste can be used in an efficient way for human consumption.

Extruded products such as pasta, noodles, and ready-to-eat snacks can also be made using coconut flour. Coconut flour is an underutilised product of coconut industry and its present use is very limited. There is immense need of commercial processing techniques to enhance utilisation of coconut flour from coconut meal. Coconut flour extruded products will be convenience products with nutritional and health benefits. Coconut flour is a high protein, fibre-rich and gluten-free functional food product.

CONFLICT OF INTEREST

Authors declare no conflict of interest.

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