Chapter 15
Nutrition and Health Aspects of Coconut

T. Rajamohan and U. Archana

Abstract Coconut provides a wide spectrum of human consumable products such as oil, kernel, tender nut water, toddy, neera, coconut sugar, immature inflorescence and haustorium. Despite enormous beneficial utilities of coconut oil, many believe that it increases blood cholesterol level, thus promoting the risk of cardiac diseases. There are enough research results to indicate the health benefits of coconut oil because of its unique fatty acid composition. Wet processing of fresh coconut kernel yields virgin coconut oil (VCO) which is very nutritious and has important health-promoting properties. Coconut oil has antibacterial, anti-protozoan and antiviral properties because of the medium chain fatty acid (lauric acid) it contains. Apart from coconut oil, coconut kernel contains many beneficial factors. Coconut kernel protein possesses cardioprotective and antidiabetic properties. Dietary fibre isolated from coconut kernel has significant hypocholesterolemic effect, and its hemicellulose component is responsible for the cholesterol-lowering action. Research indicates that tender coconut water (TCW) and mature coconut water can reduce the occurrence of lifestyle diseases. TCW consumption reduces the risk of heart disease and has significant hypocholesterolemic, antioxidant and antithrombotic effects. Furthermore, hypoglycaemic effect of mature coconut water has been reported in diabetic rats. Neera tapped from coconut inflorescence enhances digestion and has a low glycaemic index. Studies indicate that immature coconut inflorescence can lower blood glucose in diabetic rats. Coconut haustorium possessing significant cardioprotective and antioxidant properties is underscored. This chapter draws attention on the health benefits of coconut products evidenced through systematic scientific approach.

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15.1 Introduction

Coconut is a major part of the diet for many people who live in tropical regions. The main consumable products of coconut are coconut oil, coconut kernel, tender coconut water and haustorium. Most important edible products derived from inflorescence include neera, toddy and coconut sugar.

15.2 Coconut Oil

Coconut oil is prepared both in households and commercial establishments. Oil extracted by dry process from copra is called coconut oil or copra oil, and the one extracted from wet kernel is known as virgin coconut oil. Please refer to Chap. 13 for details on processing.

Coconut oil is a light coloured, saturated and stable oil of natural origin, with a pleasant aroma and pleasing flavour. It can be used for cooking without refining as a frying and seasoning oil. The oil is biodegradable and highly resistant to oxidative deterioration during frying, which makes it ideal for high-heat cooking. The unique nutritional and medicinal qualities of coconut oil are easy digestibility, absorbability and readily oxidisable nature leading to reduced fat accumulation in the body. The oil is an excellent fat source in the preparation of filled milk and infant food formulae. It is used as massage oil due to its ready penetration into the skin (CDB 2005). Coconut oil exhibits antimicrobial and antiviral properties.

15.2.1 Composition of Coconut Oil

Coconut oil contains 90–92% saturated fatty acids and about 8–10% unsaturated consisting of oleic acid (C18:1) and linoleic acid (C18:2) as triglycerides. The saturated fatty acids in coconut oil are mostly medium chain fatty acids, and lauric acid (C12:0) is the most predominant among them. In Table 15.1, the fatty acid composition of coconut oil and VCO is compared.

15.2.2 Dietary Features of Coconut Oil

Among the different edible oils, coconut oil stands out as a triglyceride with unique physical, chemical and structural characteristics. Though coconut oil is basically a saturated fat, 63.5% of the total fatty acids consist of short and medium carbon chains of 12 or less carbon atoms. Consequently, coconut oil exhibits dietary properties which are specific to the group of short and medium chain fatty acids. On the

Table 15.1 Fatty acid composition of coconut oil and virgin coconut oil

Fatty acids	Composition	Percentage	
		Coconut oil	VCO
Caprylic acid	C 8:0	8.15	8.050
Capric acid	C 10:0	5.56	5.420
Lauric acid	C 12:0	43.55	45.510
Myristic acid	C 14:0	18.38	19.740
Palmitic acid	C 16:0	8.25	7.830
Stearic acid	C 18:0	2.65	3.140
Oleic acid	C 18:1	6.70	4.700
Linoleic acid	C 18:2	1.49	1.880
Arachidic acid	C 20:0	0.086	0.086

Source: Nevin and Rajamohan (2006)

other hand, the fatty acids present in other edible oils belong to the group of long chain fatty acids which are chemically different from the short and medium chain fatty acids. The only other major source of medium chain fatty acid is palm kernel oil (Babayan 1968).

The short and medium chain fatty acids (SMCFAs) have higher solubility in water and in other biological fluids than the long chain fatty acids (LCFAs). These features facilitate the action of various lipases leading to faster and complete digestion of glycerides composed of SMCFAs. The products of hydrolysis reach the liver directly via the portal venous system and preferentially are used for energy production. Studies have revealed that supplementation of coconut oil beneficially modulates fatty acid metabolism by reducing lipogenesis and enhancing the rate of fatty acid catabolism (Arunima and Rajamohan 2014). The only limitation of coconut oil as the sole source of dietary fat is its extremely low content of essential fatty acids. However, in the major coconut-consuming regions, the local populations have access to diverse food sources such as cereals, pulses, tubers, fish, etc. which provide substantial additions of essential fatty acids (EFAs) in their daily diet. Moreover, the presence of 8–10 carbon fatty acids which constitute 15% of the total fatty acids of coconut oil diminishes the requirement of EFAs in human nutrition (Kaunitz 1983).

15.2.3 Health Effects of Coconut Oil

Although coconut oil has many beneficial uses, the propaganda against the consumption of coconut oil is still continuing and is debated due to its high saturated fat content. It is generally believed that saturated fatty acids increase blood cholesterol and thus promote the risk of heart disease. Research findings now suggest that coconut oil can make a comeback because of its unique health-promoting properties.

15.2.3.1 Coconut Oil and Heart Disease

Coconut oil, being rich in saturated fatty acid, is frequently used for investigating the saturated fat hypothesis and generally maligned as hypercholesterolemic. High intake of saturated fats is considered as a risk factor for the occurrence of coronary heart disease (CHD). Several epidemiological studies however revealed that association between saturated fat and CHD was much weaker than that predicted by international comparisons (Keys 1980), because saturated fat increases HDL cholesterol which to a great extent compensates for its adverse effect on LDL cholesterol (Sreevastava 1994). Because of the high content of saturated fats in coconut oil, there are concerns that it could lead to more atherogenic lipid profiles (Ahrens 1957; Keys et al. 1957). It is argued that coconut oil supplementation increases adverse lipids, thus, promoting the risk of heart disease (Hegsted et al. 1965; Anderson et al. 1976). But Prior et al. (1981) showed that there is no harmful effect when islanders had a high intake of coconut oil. Blackburn et al. (1989) in a review concluded that coconut oil is a neutral fat in terms of atherogenicity. Thampan (1994) highlighted the fact that people consuming large amounts of fresh coconut kernel in a varied diet in different parts of the world did not demonstrate hypercholesterolemia and coronary atherosclerosis. Though coconut is a main ingredient in the diet of Polynesians and Filipinos, their blood cholesterol levels and incidence of heart diseases are reported to be lower (Dayrit 2000).

Research studies carried out in 258 human volunteers in Kerala population, India, revealed that coconut oil consumption does not cause increase in blood LDL cholesterol, but it increases HDL cholesterol. Consumption of coconut kernel along with coconut oil had a beneficial effect in that it reduced total cholesterol and more importantly raised HDL cholesterol levels and lowered LDL cholesterol/HDL cholesterol ratio (Rajamohan 1997). Comparative studies on CAD patients consuming coconut oil and sunflower oil did not show any significant difference in the blood lipid profile, vascular function and antioxidant levels (Vasudevan 2010, Vijayakumar et al. 2016).

Researchers of Harvard Medical School have shown that coconut oil reduces the risk of heart disease due to favourable alteration of blood lipid profile (Norton et al. 2004). Assuncao et al. (2009) conducted a study in women between the age of 20 and 40 with abdominal obesity given either soya bean oil or filtered coconut oil and regularly exercised. They reported that the subjects showed weight loss and only the coconut oil administered group experienced reduction in abdominal obesity and an improved LDL cholesterol/HDL cholesterol ratio, whereas the soya bean group actually had increased total and LDL cholesterol as well as decreased HDL cholesterol levels.

Studies by Feranil et al. (2011) in premenopausal women in the Philippines showed that coconut oil intake was positively associated with beneficial lipid profiles. A review by Eyres et al. (2016) does not support the view that use of coconut oil reduces the risk of heart disease. It has been pointed out that the quantity of cooking oil is more important than the type of cooking oil in contributing to the risk of CAD (Sabitha and Vasudevan 2010). The National Lipid Association also

suggests that it is better to restrict the quantity of coconut oil, when used as part of a daily diet (Jacobson et al. 2015).

There are reports that in addition to hypercholesterolemia, free radical-mediated oxidative stress plays a key role in the occurrence of CVD (Singh and Devaraj 2006). Coconut oil is less susceptible to lipid peroxidation than unsaturated fatty acid-rich oils (Ergun et al. 2005). Free radical damage has long been believed to be a risk factor for the degenerative process which accompanies ageing. Comparative studies carried out in young and aged rats fed with coconut oil and sunflower oil indicate that the rate of tissue lipid peroxidation was less in coconut oil-fed rats when compared to sunflower oil-fed ones (Shalini and Rajamohan 2012). Feeding thermally oxidised fats increases the lipid peroxidation products in the tissues (Liu and Huang 1995). The products thus formed during oxidation have been suggested to have deleterious effects on the health of human beings and animals, since they can lead to atherosclerosis (Cohn 2002).

Studies carried out in rats showed that consumption of unsaturated fatty acid-rich cooking oil heated repeatedly at elevated temperatures is more deleterious to health compared to saturated fatty acid-rich oils such as coconut oil (Chacko and Rajamohan 2011). This study indicates that dietary oils heated repeatedly at elevated temperatures result in significant alterations in plasma lipids, peroxide levels, platelet aggregation and platelet function compared to fresh oils in rats and the deleterious effects were lower in heated coconut oil compared to heated mustard oil and sunflower oil. This observation suggests that unsaturated fatty acid-rich oils which are considered to be beneficial for consumption, when used as fresh oil, lose their beneficial effects on repeated heating.

Researchers and nutritionists are now beginning to recognise the need to distinguish features of dietary oils other than the degree of saturation. Apart from the structure and composition of triglycerides, the nature and quantity of non-glyceride components like polyphenol, tocopherols, carotenes, etc., all of which are essential factors, cannot be ignored.

15.2.3.2 Therapeutic Properties of Virgin Coconut Oil

VCO, extracted by wet processing, is very valuable because of its unique health-promoting properties. Most of the biologically active minor components are inactivated when coconut oil is extracted in the traditional method through extraction from copra which has been exposed to high temperatures. On the other hand, VCO extraction, by wet processing, retains most of the nonsaponifiable components. As in the case of coconut oil obtained from copra, VCO contains almost similar percentage of fatty acids, mainly medium chain fatty acids. In addition, it also contains higher amounts of biologically active components, viz. polyphenols, tocopherol and phytosterols with antioxidant and other beneficial properties (Nevin and Rajamohan 2004). Dia et al. (2005) revealed that VCO had higher total phenolic content compared to refined coconut oil. High total phenolic content in VCO has been reported by Marina et al. (2009) also.

Studies have been made by several investigators to determine the effects of VCO on blood lipids and lipid peroxidation and its effect on CVD. Animal studies showed that supplementation of VCO increased the HDL cholesterol compared to copra oil and groundnut oil (Nevin and Rajamohan 2006, 2009). Rats fed with VCO, copra oil, olive oil and sunflower oil showed that VCO feeding lowered the levels of total cholesterol, LDL + VLDL cholesterol, Apo B and triglycerides in serum, while HDL cholesterol and Apo A_1 were significantly higher in rats fed with VCO compared to other oil-fed groups. The increased Apo A_1 levels in VCO-fed rats were directly correlated with the increased HDL cholesterol levels (Arunima and Rajamohan 2012). Apo A_1 is the major protein component in HDL in serum, and its concentration is inversely correlated with the risk of premature atherosclerosis (Miccoli et al. 1996). These observations clearly indicate that consumption of VCO has significant beneficial effect on lipid metabolism than coconut oil extracted from copra.

Tissue lipid peroxidation has been linked to aetiology of various degenerative diseases (Halliwell 1997). The increased lipid peroxidation leads to the oxidative modification of LDL which plays a major role in pathogenesis of atherosclerosis (Dillon et al. 2003). Studies demonstrated that feeding VCO increases the antioxidant status, preventing the oxidative damage of lipids and protein oxidation (Arunima and Rajamohan 2013). It also possesses significant antithrombotic effect by inhibiting the activation of platelets and coagulation factors compared to rats fed with copra oil, olive oil and sunflower oil (Arunima and Rajamohan 2016). These findings indicate that supplementation of VCO has significant cardioprotective effects. The potential benefits of VCO in maintaining lipid levels, antioxidant status and antithrombotic effects are due to the presence of lauric acid and biologically active unsaponifiable components like polyphenols, tocopherols and phytosterols. Wet processing of VCO helps to retain higher amounts of polyphenols which is capable of reducing lipid levels and lipid peroxidation (Marina et al. 2009; Nevin and Rajamohan 2006; Mansor et al. 2012).

Administration of VCO ameliorates blood glucose and oxidative stress in diabetic rats (Iranloye et al. 2013; Akinnuga et al. 2016). Kochukuzhiyil et al. (2010) demonstrated that coconut oil-enriched diet helps to prevent accumulation of body fat and prevents insulin resistance. In type 1 diabetes, brain function can be improved by medium chain fatty acids found in coconut oil (Page et al. 2009). MCFA in coconut oil regulates blood sugar and increases insulin secretion and insulin sensitivity (Garfinkel et al. 1992; Han et al. 2003).

15.2.3.3 Coconut Oil and Antimicrobial Property

The antimicrobial properties of the medium chain fatty acids found in coconut oil have been known to researchers since 1966. Coconut oil is predominantly composed of medium chain fatty acids (MCFA), lauric, capric and caprylic acids. All the three of the medium chain fatty acids and medium chain triglycerides possess antimicrobial properties (Kabara et al. 1972). According to published reports, lauric

acid is one of the best inactivating fatty acids, and its monoglyceride (monolaurin) is the most effective one (Kabara et al. 1972; Sands et al. 1979; Fletcher et al. 1985). Bacteria, yeast, fungi and enveloped viruses are inactivated by monolaurin. The lipid membranes of the microorganisms are inactivated by the medium chain fatty acids and their derivatives (Isaacs and Thormar 1991; Isaacs et al. 1992). Hornung et al. (1994) have shown that the antimicrobial effect in viruses is related to monolaurin's interference with virus assembly and viral maturation. However, Projan et al. (1994) reported that one of the antimicrobial effects in bacteria is related to monolaurin's interference with signal transduction/toxin formation. Ogbolu et al. (2007) indicated the possibility of using coconut oil in the treatment of fungal infections, in view of its antifungal activity against *Candida* spp. especially since some of the *Candida* species are becoming drug-resistant.

Monolaurin also inactivates the protozoan parasite *Giardia lamblia.*

15.2.3.4 Other Beneficial Properties

Studies demonstrated that VCO has potential beneficial effects in arthritis-induced rats (Vysakh et al. 2014). The anti-inflammatory and antioxidant effects of VCO which help to prevent CVD are due to its higher phenolic fraction. VCO has also been proved to have a positive effect on Alzheimer's disease (AD). Phenolic compounds of coconut oil may inhibit the aggregation of amyloid β peptide, a key step in the pathogenesis of AD (Porat et al. 2006). Coconut oil is easily absorbed and metabolised by the liver and can be converted into ketones. Ketone bodies may be beneficial to people developing or already suffering from memory impairment as in AD since they are important alternate energy sources in the brain (Fernando et al. 2015). Coconut oil has a beneficial role in colon cancer (Reddy and Maeura 1984) and breast cancer also (Cohen et al. 1984). Lauric acid is known to show anticancer activity by its ability to induce apoptosis (Fauser et al. 2013).

15.3 Tender Coconut Water (TCW)

TCW is a clear liquid found inside the tender coconut of 6–8 months' maturity. It has been a popular refreshing drink in the tropical countries, either served fresh, chilled or packed. Coconut water possesses several properties beneficial to human health (Pradera et al. 1942; Anurag and Rajamohan 2003a). Coconut water contains several bioactive components, viz. sugars, electrolytes, minerals, vitamins, amino acids, phytohormones, cytokinins and enzymes such as catalase, dehydrogenase, polymerases, etc. As it contains plant enzymes and sugar, TCW undergoes biochemical changes and loses its quality once the nuts are harvested. Various efforts have been made to preserve the quality and increase the shelf life of TCW through acidification, pasteurisation, etc. Technology is available to extend the shelf life of TCW by packing in flexible pouches and aluminium beverage containers (CDB 2017).

15.3.1 Chemical Constituents of Coconut Water

Coconut water contains minerals, sugars, vitamins and proteins besides growth-promoting factors and neutral fats. The composition of coconut water depends upon various factors like variety, nut maturity, soil features and climatic conditions (Msengi et al. 1985; Jayalakshmi et al. 1986). The major chemical constituents are sugars and minerals, the minor ones being fat, proteins and other nitrogenous substances (Chavalittamrong et al. 1982). Sugar content in the nut water increases from 1.5% to 5 to 5.5% during nut development and decreases to about 2% at full maturity (Child and Nathanael 1950). In the fully mature nut, sucrose content is approximately 50% of total sugar (Marar 1958).

The nitrogen and total protein concentration increases with maturity (Birosel et al. 1976; Jayalakshmi et al. 1986). The predominant proteins are globulin, albumin, glutelin and prolamine. Even though coconut water is not a good source of protein, it contains most of the amino acids (Suresh et al. 1968; Baptist 1956). In the ripening nut, the free amino acids increase from 4 mg to 16 mg 100 ml^{-1} (Shivashankar 1991). Among the free amino acids, L-arginine constitutes the major fraction. TCW contains 30 mg% of L-arginine (Sandhya and Rajamohan 2006). Fat is a minor constituent, and changes occur in fat content and fatty acid composition during maturity (Jayalakshmi et al. 1986). A comparison of the composition of TCW and mature coconut water (MCW) is presented in Table 15.2.

Coconut water is an abundant source of minerals. Composition analysis of TCW showed that it contains 300 mg/dl potassium. TCW is one of the best sources of electrolytes. The liquid endosperm containing nuclei as well as both positive and negative ions makes it a biological electrolyte (Bamunuarachchi and Ranaweera 2007). It contains almost the same level of electrolyte balance as in the blood (Suresh et al. 1968).

Tender nut water is a rich source of vitamin C (25 mg/dl) which is an important water-soluble antioxidant and acts as a radical scavenger. It also contains polyphenols (Bhagya et al. 2010a). Another useful component present in the water is phytohormones, namely, cytokinins (Kende and Zeevart 1997). Research studies suggest

Table 15.2 Composition of tender (TCW) and mature coconut water (MCW)

Constituents	TCW	MCW
Total sugar (%)	4.8	3.1
Total reducing sugar (%)	4.0	2.0
Total protein (mg/dl)	150	450
L-arginine (mg/dl)	30	150
Vitamin C (mg/dl)	25	15
Magnesium (mg/dl)	16	14
Potassium (mg/dl)	300	257
Calcium (mg/dl)	40	44

Source: Sandhya and Rajamohan (2008)

that cytokinins (e.g. kinetin and trans-Zeatin) show anti-ageing, anticarcinogenic as well as antithrombotic effects (Vermeulen et al. 2002). The natural pH of coconut water varies between 4.9 and 5.2. The acidity may be due to the organic acids and free amino acids present (Jayalakshmi et al. 1986). Dissolved CO_2 evolved during tissue respiration, and also fatty acids contribute to acidity.

15.3.2 Therapeutic Properties of Tender Coconut Water

Tender coconut water (TCW) is consumed all over the world not only because it is a refreshing drink but also because of its numerous therapeutic qualities. TCW has a unique composition of vitamins, minerals, amino acids, phytohormones and sugars due to which reason it is very useful in the upkeep of health (Yong et al. 2009). The most important use of TCW is as a rehydration medium (Pummer et al. 2001). TCW is also used as a blood plasma substitute and is readily accepted by the body (Anzaldo et al. 1975). The water is reported to be beneficial to bladder infections, kidney stones and sexual vitality (Macalalag Jr and Macalalag 1987). TCW is recommended as the best treatment for diarrhoea in children (Cooper 1986). It is also reported to contain substances capable of rapid proliferation of plant tissues (Tulecke et al. 1961) and has been used as a bacterial and plant tissue culture media (Smith and Bull 1976; Marquez et al. 1987).

Shah (1956) showed that intake of tender coconut water reduces the risk of heart disease. TCW has significant hypocholesterolemic, antioxidant and antithrombotic effects as evidenced from experimental rats with induced myocardial infarction (Anurag and Rajamohan 2003b). Feeding TCW showed improved activities of mitochondrial enzymes and provided protection against free radical-mediated damage, induced by isoproterenol (Anurag and Rajamohan 2003b). Pretreatment with TCW decreased the clotting and showed antithrombotic effects in rabbits with induced myocardial infarction. Studies using TCW and thrombolytic drug, streptokinase, showed similar thrombolytic effects, while the antioxidant effects were more with TCW (Prathapan and Rajamohan 2010). In another study, feeding TCW showed hepatoprotective and antioxidant effects in carbon tetrachloride-intoxicated rats (Anthony and Rajamohan 2003). TCW has a beneficial effect on blood pressure and lipid levels in fructose-fed hypertensive rats (Bhagya et al. 2010a). When such rats were treated with TCW, the blood pressure could be kept under control. The levels of serum lipids were higher in hypertensive rats compared to normal ones. Treatment with TCW decreased the levels of total cholesterol, triglycerides and free fatty acids both in serum and tissues. In fructose-fed hypersensitive rats, tender coconut water had a beneficial effect as far as aldosterone level, plasma renin activity and electrolyte imbalance are concerned (Bhagya et al. 2010b). Alleyne et al. (2005) also showed that consumption of TCW is effective in bringing about the control of hypertension.

15.3.3 Health Effects of Mature Coconut Water

While tender coconut water is mainly consumed as a natural drink, mature coconut water (MCW) is usually discarded. According to Sandhya and Rajamohan (2008), compared to TCW, MCW is superior in hypolipidemic action in cholesterol-fed rats. The quantitative difference in the composition of the active components in MCW is the reason for its superiority. Comparative studies using tender and mature coconut water indicated that administration of MCW had significant hypoglycaemic effect in diabetic rats and reduced the pancreas damage induced by alloxan and stimulated beta-cell regeneration (Preetha et al. 2013a). Comparative evaluation of lyophilised MCW and glibenclamide in alloxan-induced diabetic rats revealed that MCW has beneficial effect against diabetic-induced complications and its effects were comparable to those of the standard drug, glibenclamide (Preetha et al. 2013b). The defects of hyperlipidemia and lipid metabolism in diabetic rats were significantly reduced by MCW (Preetha et al. 2013c). Treatment with MCW and L-arginine exhibited significant antithrombotic activity in diabetic rats, which was evidenced from the reduced level of WBC, platelets, fibrin and fibrinogen. In addition, the activity of nitric oxide synthase in the liver and plasma arginine content and urinary nitrite was higher in MCW treated rats, and the effects were comparable with L-arginine-treated group (Preetha et al. 2015). This finding indicates that L-arginine in coconut water is one of the major factors which ameliorates the alterations in blood glucose, lipid levels and coagulation factors through the increased nitric oxide availability. Diabetes has a degenerative and destructive effect on the kidney which can be partially but significantly reversed by concomitant administration of coconut water (Nwangwa 2012).

15.4 Coconut Kernel

Since ancient times, coconut has been used as a vital source of food in many of the tropical countries. It is a major culinary ingredient in recipes in several parts of India, particularly in Kerala. Coconut kernel is a complete food rich in calories, vitamins and minerals. The kernel contains potassium, calcium, magnesium, manganese, iron, copper, phosphorus, sulphur and chlorine as well as vitamins, namely, thiamine, ascorbic acid, vitamin A, tocopherol, phenolic compounds and phytohormones. Fresh coconut kernel contains 7% dietary fibre and 5% proteins, in addition to coconut oil. Presence of these macro- and micronutrients in fresh coconut kernel is one of the reasons behind its biological effects. Studies indicate that consumption of coconut oil alone has less beneficial effects on blood cholesterol levels than that of coconut kernel along with coconut oil (Padmakumaran Nair et al. 1998a).

15.4.1 Coconut Kernel Protein (CKP)

The coconut protein is known to be of good nutritional quality. Seventy to eighty percent of the coconut kernel proteins are globulins, which are good protein from the point of view of digestibility and biological value. Amino acid analysis of the protein carried out by Salil et al. (2011) revealed that it has a much higher amount of L-arginine. The health benefits of coconut kernel protein are mostly due to the presence of L-arginine. Coconut kernel possesses significant hypolipidemic effect (Padmakumaran Nair et al. 1998b). Coconut kernel protein has a significant cardioprotective effect on isoproterenol-induced myocardial infarction in rats (Mini and Rajamohan 2002). Studies have shown that diet containing coconut kernel protein protects the heart by beneficially modulating endothelial nitric oxide synthase and antioxidant mechanism due to its ability to inhibit tumour necrosis factor-alpha and nuclear factor-kappa B activation in isoproterenol-induced myocardial infarction (Remya et al. 2013). Dietary supplementation of coconut kernel protein may have greater significance in reducing the extent of oxidative stress and inflammatory responses associated with myocardial infarction. The results show that the oxidative stress during isoproterenol administration in rats was alleviated effectively by coconut kernel protein, possibly due to the presence of L-arginine. The beneficial effects of coconut kernel protein in reducing glucose, enzymes and insulin facilitating carbohydrate metabolism in diabetic rats have been proved by the studies undertaken by Salil et al. (2011). Coconut kernel protein reversed the damage caused to the pancreas by alloxan as evidenced from the histopathological studies.

15.4.2 Coconut Kernel Fibre

Coconut kernel is an excellent dietary fibre source. It is prepared from finely ground, dried and defatted coconut kernel. It has the highest dietary fibre content than any other dietary fibre supplements and has all the benefits of other dietary fibres. Studies revealed that coconut fibre has significant hypocholesterolemic effect, and the results indicate that its hemicellulose component may be responsible for the cholesterol-lowering action (Sindhurani and Rajamohan 1998). Chemical composition of neutral detergent fibre (NDF) isolated from coconut kernel contains hemicellulose (45.10%), cellulose (43.28%), lignin (8.15%), cutin (3.28%) and silica (0.25%). Investigations suggest that inclusion of coconut fibre in the diet results in significant hypoglycaemic action (Sindhurani and Rajamohan 2000). Feeding dietary fibres isolated from coconut kernel and black gram showed significant decrease in serum and tissue lipids and lipid peroxides in high-fat diet-fed rats (Thampi et al. 1991). The fibre contained in the coconut kernel has a protective role in the prevention of

1,2-dimethylhydrazine-induced colon carcinogenesis (Manoj et al. 2001). Protective effect of coconut cake against colon carcinogenesis has also been reported (Nalini et al. 2004). In addition, the beneficial role of minor components such as phytohormones and phenolic compounds present in coconut kernel in preventing Alzheimer's disease has also been reported (Fernando et al. 2015).

15.5 Other Edible Coconut Products

15.5.1 Coconut Haustorium

Haustorium is a spongy part developed from the basal part of the embryo during germination, filling the entire cavity, in 8–16 weeks. During this period, it mobilises nutrients in the endosperm and nourishes the germinating embryo (Balachandran and Arumughan 1995). It is a nutritious and tasty tropical delicacy. Coconut haustorium contains about 66% carbohydrates in which 64% is sugar. It is a rich source of phenolics and has high antioxidant capacity (Arivalagan et al. 2018). The haustorium is a rich source of phosphorus and potassium and can be used as an additive in food for children (Konan et al. 2017). It is a good source of sucrose, fructose, glucose, phosphorous and potassium. Studies have shown that during germination, the total starch content of haustorium increased linearly, whereas reducing and soluble sugars decreased rapidly and remained in a steady state thereafter. The excess carbohydrates mobilised from the kernel are stored in the haustorium as starch (Balasubramaniam et al. 1973).

Studies using aqueous extract of coconut haustorium indicated cardioprotective and antioxidant properties during isoproterenol-induced myocardial infarction in rats (Chikku and Rajamohan 2012, 2013). In the myocardium of coconut haustorium pretreated rats, activities of antioxidant enzymes increased, and peroxidation products decreased. Histopathological examination of the heart of isoproterenol administered rats showed extensive cardiac damage, while rats pretreated with aqueous extract of haustorium showed minimal histological changes. These findings clearly show that coconut haustorium has significant cardioprotective property. Fresh coconut haustorium is enriched with phytoconstituents such as proteins, carbohydrates, terpenoids and flavanoids which possess strong anti-inflammatory and antioxidant activities (Abiraami Valli and Uma Gowri 2017). These workers reported the presence of squalene, a terpenoid showing strong antiulcer affinity against *Helicobacter pylori*, an ulcer-causing bacteria, and recommended coconut haustorium as a natural, economically potent food source for human health. Coconut haustorium can be used to improve foetal growth and development in polytocous animals by reducing foetal number (Sumiaty et al. 2017).

15.5.2 Coconut Inflorescence

Coconut inflorescence is used for production of diverse products for human consumption.

15.5.2.1 Value-Added Products from Coconut Inflorescence

Coconut Sap The coconut sap (neera, also called palm nectar) is the sap extracted from the inflorescence of coconut which is sweet, translucent and high in nutritional value. Due to its very good taste, it has attained popularity as a soft drink. But one of the issues is its short life. This has been overcome through technologies developed by ICAR-CPCRI and KAU (Kerala Agricultural University) for collecting fresh, hygienic and unfermented coconut inflorescence sap (Jayaprakash et al. 2013, CPCRI 2016). For details please see Chap. 13.

Neera is known to improve digestion and enable clear urination. Since its glycaemic index is only 35, neera can be consumed even by diabetic patients. Neera is rich in carbohydrates and sugar (10–15%), and its pH is almost neutral. It is a rich source of amino acids, antioxidants and vitamins such as nicotinic acid, vitamin C and vitamin B complex (Aalbersberg et al. 1997; Hebbar et al. 2015). The composition of neera is given in Table 15.3.

Coconut Toddy When fermented, neera becomes toddy due to conversion of sugar to alcohol (Iwuoha and Eke 1996). Coconut toddy, also known as palm wine, is a sweet alcohol beverage. It is known by many names in different regions and is a common drink in various parts of Asia, Africa, the Caribbean and South America. In small quantities, it cures intestinal disorders and insomnia. In some areas toddy is evaporated to produce unrefined sugar called jaggery.

Table 15.3 Composition of neera

Total sugar	18–20%
Vitamin C	1.3 mg/100 ml
p^H	6.8
Acidity	10.0 meq/l
Phenols	8.0 mg/1009 ml
Minerals	
Potassium	90.5 ppm
Calcium	60.0 ppm
Phosphorus	15.0 ppm
Iron	45.0 ppm
Sodium	9.5 ppm

Source: Jayaprakash et al. (2013)

Coconut Sugar Coconut sugar is produced from neera. Neera is boiled over moderate heat until most of the water is evaporated. As the water evaporates, it starts to transform into fine granules of sugar. Coconut sugar is subtly sweet, almost like brown sugar. It is used as a sweetener in many countries. Coconut sugar contains 70–79% sucrose and nearly 3% of both glucose and fructose (Purnomo 1992). Coconut sugar also contains several nutrients, viz. proteins, minerals, short chain fatty acids, polyphenols and antioxidants. According to the Philippine Department of Agriculture, coconut sugar has a low glycaemic index (GI) of 35 which is much lower than the value of table sugar (GI 60). Lower glycaemic index value of coconut sugar has also been reported by others (Trinidad et al. 2010; Srikae and Thongta 2015). Consumption of low glycaemic index diets is recommended because it decreases the risk of developing diabetes and cardiovascular disease (Jenkins et al. 2002). Palm sugars contain a fibre called inulin, which may decrease glucose absorption (Trinidad et al. 2010; Vayalil 2012).

Inflorescence Cream A creamy preparation obtained from young inflorescence is used to cure backache in Indian traditional medicine. Young coconut inflorescence (20% w/w)-containing diet has beneficial effect in diabetic rats. It improves glucose homoeostasis and antioxidant status in diabetic rats (Renjith and Rajamohan 2012b). Onset of hyperglycaemia resulting from alloxan administration was prevented by a lowered blood glucose level resulting from a treatment with inflorescence. In diabetic rats, activity of antioxidant enzymes declined, while their activities were reverted to normal range in inflorescence-supplemented animals. The young coconut inflorescence exhibited protective and ameliorative effects against alloxan-induced pancreative cytotoxicity and severe hyperglycaemia and also in repairing and rejuvenating the residual beta-cell population (Renjith and Rajamohan 2012a). These effects may be due to the presence of phenolic acids, flavanoids and other phytoconstituents which could act synergistically or independently in modulating the activities of glycolytic and gluconeogenic enzymes.

15.6 Future Strategy

It is advantageous to the coconut industry, if coconut moves out of the oil sector, to the extent possible, taking full advantage of its health and nutritional properties in view of the strong competition from other vegetable oils. Although the medicinal value of coconut and coconut products has been clearly indicated from experiments on animals, it is necessary to validate these by bringing in concrete evidence on its therapeutic properties and mode of action in curing specific diseases. With the growing demand for virgin coconut oil, it is important that the quality characteristics of the oil are studied and improved.

It is now necessary to follow up the traditional knowledge and the effects from animal studies to clinical outcomes for prevention and treatment of various diseases. In addition, studies are warranted using underutilised factors for exploring the

medicinal benefits. The recognised medicinal properties of coconut oil by the traditional medical systems have to be validated through continued studies on dietary and medicinal qualities of coconut oil.

It is encouraging that many laboratories are undertaking research on coconut oil. Carefully controlled research is necessary before we can determine the long-term impact of coconut oil, especially in the case of long-term progressive dementias such as Alzheimer's disease or related disorders.

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