



Coconut Testa – a Valuable by-product of Coconut Oil Industry

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Introduction

The brown skin covering the coconut kernel is testa, mainly a by-product obtained from coconut processing industries. During the preparation of desiccated coconut, coconut milk, and virgin coconut oil, the testa is removed by paring the dry/wet coconut as it imparts a brown color to the oil and a dull appearance to other products. As the coconut matures, the thickness of the testa increases and gives brown color to the bottom layer of the kernel. Testa earlier was usually used as animal feed, and raw material for the production of bio-diesel. In contrast, nowadays, it is used in bakery products as a substitute for wheat flour and feed. It is found that coconut testa flour substitution of up to 30 % was acceptable without affecting the overall quality of cookies. The use of 5 % coconut testa in fish feed showed that the growth rate of the red tilapia breed was effective.

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The potential of coconut testa, oil and cake in India

Currently, over 150 desiccated coconut powder production units are present in India, of which the total production capacity of all the production units would come around one lakh metric tones. India is one of the largest exporters of desiccated coconut powder globally, next only to the Philippines. Coconut testa constitutes about 18% of the total dry weight of kernel. About 23.7 thousand tonnes of testa is produced annually in Hainan Island, Sri Lanka. In India, about 88,884 tons of testa is available to produce oil and other value-added products. Worldwide, the production of testa waste is still more and hence needs alternative ways to reuse it as valuable products. Table 1 shows data on the potential availability of testa (88,884 tonnes), testa oil (44,442 tonnes), and testa cake(44,442 tonnes) valued at Rs.1200 crores per annum.

Proximate composition of testa

Proximate composition of dry and wet coconut and dry and wet coconut kernel and the dry and wet coconut testa has been reported in various studies. A study by Prakruthi Appaiah et al. (2014) was based on laboratory scale dry and wet coconut testa and the dry and wet coconut kernel, and the starting whole dry and wet coconut. The proximate composition of dry coconut (copra) whole, copra testa, and testa removed coconut (copra) kernel had moisture 3.6-4.3%; fat 59.0 – 63.6%; protein 8.1 – 10.2%; carbohydrates 22.4 – 26.3%; ash 1.4 – 2.1%; and potassium was the major mineral present at 120.3 – 124.1 mg%. The proximate composition of wet coconut whole, wet coconut testa, and testa removed wet coconut kernel, had moisture 32.9 – 43.5%; fat 34.7 – 38.8%; protein 6.2 – 7.5%; carbohydrates 10.6 – 24.6%; crude fibre 11.7 – 17.2%; ash 0.7 – 1.0%; and potassium was the major mineral present at 107.8 – 123.8 mg%. The coconut testa contained other minerals like sodium, calcium, iron, and zinc. The samples had fat as a major component ranging from 34.7 to 63.6 %. Dry coconut testa yields more oil than wet coconut testa, and wet coconut kernels and dry coconut kernels yield almost the same amount of oil expressed on a dry basis. But the amount of oil present in the testa is found to be lower than in the kernel. Marasinghe et al., 2019 investigated the proximate composition of four local cultivars, namely San Raman, Gon Thambili, Ran Thambili, and Tall x Tall, and compared with the commercial hybrid grown in Sri Lanka. These had moisture content of 2.27 -4.27 %, crude fat content 7.93 – 23.49 %, crude protein 23.83 – 32.22 %, ash content 3.7 - 5.3 %, and total carbohydrate content by difference 42.55 – -4.27 %, crude fat content 7.93 – 23.49 %, crude protein 23.83 – 32.22 %, ash content 3.7 - 5.3 %,



and total carbohydrate content by difference 42.55 – 59.24% respectively. Compared to Indian coconut these had a higher protein content probably due to varietal differences.

Physico-chemical characteristics of coconut testa oil/coconut pairing oil

Some of the physico-chemical characteristics of commercial coconut oil and laboratory solvent extracted coconut testa oil from India and the commercial coconut oil and commercial coconut testa oil (coconut pairing oil) from Sri Lanka are given in Table 2. Only fatty acid composition and iodine value are available for commercial Sri Lankan coconut pairing oils compared to normal commercial coconut oil. Coconut pairing oil is allowed as an edible oil in Sri Lanka. The data is not available for the Indian coconut pairing oils, probably because the pairing oil is not allowed as an edible oil in India. However, the data provided by Prakruthi Appaiah et al. (2014) for the laboratory solvent extracted testa oil shows the variation in fatty acid composition and iodine value among the testa oil, coconut whole, and kernel oils.

TABLE 1. The potential availability of coconut testa, testa oil, and testa cake in India

Production of coconuts	Dry coconut whole (copra)	Dry coconut testa (18% of copra) ***
India*,**	2469 million nuts	444.42 million nuts equivalent
Potential in tones		444.42 million nuts x 200g/nut = 88,884 tones (4% moisture basis) valued at Rs.60/kg = INR 533.3 crores
Potential of oil (50% basis)	-	44,442 tones valued at Rs.1111.1Crores (Rs.250/kg oil)
Potential of cake (50% basis)	-	44,442 tones valued at Rs. 88.9 Crores (Rs.20/kg)
Total value (oil +cake)	-	INR 1200 crores

*Jnanadevan R. Coconut sector experiencing an all-time high price. Indian Coconut Journal. February 2018, pages 8-11.
 **Current coconut production reported is 21,206.74 million nuts during 2019-20, internet data from CDB website 11th October 2021).
 *** Marikkar and Madhrapperuma, 2012

TABLE 2. Some physico-chemical characteristics of commercial coconut pairing (testa) oil and coconut oil in comparison to Indian commercial Coconut oil and lab prepared coconut testa oil

Parameters	*Sri Lankan commercial Coconut (copra) oil	*SriLankan coconut(copra)testa oil (also known as coconut pairing oil)	***Indian commercial Coconut (copra) oil*	****Indian coconut testa oil (laboratory prepared-testa solvent extracted)
Moisture	na	na	na	na
Colour (Lovibond unit)	na	na	2.4	na
Peroxide value meq O ₂ /kg	na	na	2.67	na
Free fatty acid value (as % lauric)	na	na	0.32	na
Iodine value Wij's cgl ₂ /g	4.75	17.46	5.3	na***** (20.60)
Saponification value mg KOH/g	na	na	255.1	na
Fatty acid composition (relative area %)	**Sri Lankan coconut oil (CNO-3)	**Sri Lankan testa oil (CPO-3)	***Indian coconut oil MYS-1	****Indian coconut (copra) testa oil
C8:0	5.06	3.23	8.06	3.9
C10:0	4.45	3.17	5.78	3.8
C12:0	48.47	36.78	51.66	40.9
C14:0	21.15	22.49	21.05	20.9
C16:0	9.08	13.32	8.64	11.3
C18:0	2.75	0.42	0.28	1.6
C18:1	6.57	17.88	4.01	12.2
C18:2	2.63	2.62	0.53	5.3
SFA	90.96	79.5	95.47	82.5
MUFA	6.57	17.88	4.01	12.2
PUFA	2.63	2.62	0.53	5.3
MCFA	57.98	43.18	65.5	48.6
Iodine value Wij's	4.75	17.46	5.3	-
*J.M.N.Marikkar and A.R.Nasyrah. Distinguishing Coconut Oil from Coconut Paring Oil using Principle Component Analysis of Fatty Acid Data, Cord 2012, 28(1) 9;				
**Sri Lankan specification for coconut oil SLS 32: 2002 amended in 2009 of 2009-03-30. AMD 387. AMENDMENT NO: 1 APPROVED ON 2009-03-30 TO SLS 32: 2002. AMENDMENT NO: 1 TO SLS 32: 2002. SPECIFICATION FOR COCONUT OIL. (SECOND REVISION).				
*** PK Prasanth Kumar and AG Gopala Krishna (2015) Physico chemical characteristics of commercial coconut oils produced in India. Grasas Y Aceites, 66(1) Jan.-Mar. 2015 e062.				
**** Prkruthi Appaiah, Sunil L., Prasanth Kumar PK, and Gopala Krishna AG. 2014, Composition of coconut testa, coconut kernel and its oil. J.Amer. Oil Chem. Soc., 91, 917-924.				
*****Calculated from fatty acid composition refer to Table 4footnote, na = not available				

Similarly, testa oil differed in fatty acid composition and iodine value with commercial coconut oil. A lower lauric acid content for testa oil was observed, and a higher oleic and linoleic acid content was observed. The data shows that the testa oil has lesser saturated fatty acid content and a slightly higher MUFA and PUFA content than the normal coconut oil. However,

the fatty acid composition of coconut/ testa/ kernel oils from both countries was almost similar.

Chemical composition of coconut testa oil

Till now, testa oil has not been allowed in India for edible purposes, although a few proprietary products are available commercially. Prkruthi Appaiah et al.

Table 3: Fatty acid composition of oils from dry and wet coconut (whole, testa, testa removed kernel) (Prakruthi Appaiah et al. 2014)

Fatty acid (%)	Dry coconut (copra) whole	Dry Coconut (copra) testa	Dry Coconut (copra testa removed) kernel	Wet coconut whole	Wet Coconut testa	Wet Coconut (testa removed) kernel
Caprylic	9.6	3.9	6.7	8.1	1.6	5.6
Capric	6.4	3.8	6.2	7.8	2.2	5.8
Lauric	51.5	40.9	52.6	50.5	32.4	52.8
Myristic	19.1	20.9	18.9	16.1	20.2	19.2
Palmitic	6.9	11.3	7.4	6.8	14.1	7.4
Stearic	1.1	1.6	1.9	2.3	1.2	1.9
Oleic	4.3	12.2	4.8	5.6	17.8	5.5
Linoleic	1.1	5.3	1.6	1.8	10.6	1.0
SFA	94.6	82.5	93.7	92.6	71.6	92.7
MUFA	4.3	12.2	4.8	5.6	17.8	5.5
PUFA	1.1	5.3	1.6	1.8	10.6	1.0
MCFA	67.5	48.3	65.5	66.3	36.2	64.2

Calculated iodine value from fatty acid composition: $IV = 0.9007 \times \%oleic + 1.8143 \times \%linoleic + 2.7410 \times \%linolenic$ acid; $IV = 5.87, 20.60,$ and 7.23 for dry copra whole oil, testa oil, and testa removed kernel oil, respectively; $IV = 13.35, 35.26,$ and 6.77 for wet coconut whole oil, testa oil, and testa removed kernel oil, respectively.

(2014) studied the chemical composition of testa oil in detail to make use of it as an edible oil similar to coconut oil. Table 3 shows the fatty acid composition of oil from dry coconut (copra) testa. The oil has a fatty acid composition similar to that of normal coconut oil. However, the content of fatty acids viz., lauric acid, palmitic acid, oleic acid, and linoleic acid show a low to high trend for the testa oil. Lauric acid showed a low value of 40.9 % compared to 51.5 – 52.6% for the kernel oils. Table 3 shows the fatty acid composition of wet coconut testa oil and the coconut whole and kernel oils. A still lower lauric acid content of 32.6% and a still higher amount of oleic and linoleic acids, 17.8% and 10.6%, were observed for the wet coconut testa oil than the dry coconut (copra) testa oil of 40.9%, 12.2%, and 5.3% respectively. The testa oil has a lower amount of SFA, MCFA, and higher amount of MUFA, PUFA, and hence a higher iodine value for the testa oils, which is normally provided for specifications for coconut oil. Marikkar and Nasyrah (2012) have shown that coconut pairing oil could be differentiated from normal coconut oil based on their fatty acid composition and iodine values considering the pairing oil and coconut oil produced in Sri Lanka. The SFA (SFA+MCFA) contents were lesser than about 90-92%, which is generally attributed to normal coconut oil (Prasanth Kumar and Gopala Krishna 2015)

The triacylglycerols content of dry testa oil and wet testa oil were almost similar, and that of dry

coconut whole and kernel oil was slightly lower than that of the wet coconut whole and kernel oils. The oils from CT and WCT contained 94.1 % and 96.4 % TAG, 5.3 % and 3.2 % of DAG, and 0.6 % and 0.4 % of MAG, respectively. CT and WCT oils contained slightly higher DAG content than testa removed kernel oils. The triacylglycerol composition of dry coconut (copra) testa oil and coconut whole and kernel oils shows variation in the composition for the dry coconut testa oil with regard to the content of trilaurin, LaMM, which was true for the wet testa oil. A lower amount of trilaurin is found in testa oils (wet. 12.34% and dry 15.9%), and a moderate amount of LaMM (wet 4.91% and dry 14.3%) is found



Copra testa



for both wet and dry testa oils. The oil from WCT had a slightly higher triolein content of 3.35% than other coconut oil samples of 0.15%. For normal commercial coconut oils, the trilaurin content of 20.67% and LaMM of 9.7%, have been observed. In general, the MUFA and PUFA (oleic and linoleic acids) of testa oils are distributed more in the triacylglycerols. In contrast, the SFA (SFA+MCA) are distributed more in the triacylglycerols of normal coconut oils.

An analysis of tocopherol and tocotrienol composition for dry and wet coconut testa oils and the dry and wet coconut whole and kernel oils show that both dry and wet coconut testa oils contained higher amounts of tocopherols and tocotrienols of 22.3 mg% and 100.14 mg% than the respective coconut whole and kernel oils of 2.9 – 6.7 mg% for dry and 2.5- 4.4 mg% for wet whole and kernel oils. Dry and wet testa oils contained 42.52mg %, 50.97mg% of phytosterols, 22.3mg%, 100.1mg% of tocopherols+tocotrienols, 1.9mg%, 0.5mg% of phenolics, 313.9µg%, 389 µg% of phenolic acids respectively. The normal commercial coconut oils have a phytosterol, tocopherol, and phenolics content of 74.5mg%, 1.2mg%, and 8.2mg%, respectively. These studies indicated that the oil from coconut testa (wet and dry) contained more natural antioxidants and probably conferred better health benefits than normal coconut oil. A study by Arivalagan et al., 2018 has reported that phenolics composition of coconut testa oils and a total of 28 phenolics were reported, of which 16 were phenolic acids and 12 were flavonoids. The primary phenolic acids found were protocatechuic acid, p-coumaric acid, and ferulic acid, whereas the principal flavonoids found were catechin, apigenin, and kaempferol.

Phytochemical composition of testa extract

The analysis of phytochemical composition and antioxidant activity of extracts from commercial wet and dry coconut, testa, and cakes found that the Copra Testa Extract (CTE) and wet Coconut Testa Extract (WCTE) contained carbohydrates, amino

acids, glycosides, triterpenes, tannins, flavonoids, phenolics, and saponins. The extracts were rich in phenolics, flavonoids, tocopherols, and tocotrienols, confirmed by HPLC. These contained high amounts of total phenolics 1.3g%; 6.3g%, total flavonoids content 2.3g%, 12.6g%; and phenolic acids 100.7mg%, 195.2mg% , tocopherols+tocotrienols content 18.7 mg%, 49.2 mg%; for dry and wet coconut testa extracts respectively compared to coconut whole and kernel extracts. A very low IC50 value of 0.06 mg/ml was observed for wet coconut testa extract. This study showed that the WCTE had high antioxidant properties and many phytochemicals compared to other coconut testa extracts. The extracts from coconut testa and seed coats of four different varieties of beans were investigated for total phenolic content, antioxidative and antidiabetic properties (Adekola et al., 2017) The study showed that the coconut testa and red kidney bean were found to have better antioxidant activity when compared to other seed coats. The study also showed that the coconut testa had strong α -glucosidase inhibition, an effective anti-diabetic agent. Ojha et al. (2019) showed that coconut testa extracts contain various polyphenolic and non-phenolic natural antioxidants, anti-inflammatory and antimicrobial compounds. The studies showed that coconut testa is a natural source of multiple phenolics, phenolic acids, and flavonoids with potent antioxidant capacity and may be used as a natural source of antioxidants.

Coconut testa oil, extracts and its probable health benefits in experimental animals:

Extraction, physicochemical properties, and fatty acid composition analysis of coconut testa oil (CTO), antioxidant activity, and the protective effect on oxidative damage to human serum albumin (HSA) of coconut testa oil extract (CTOE) were investigated (Zhang et al., 2016) Results showed that the optimal extract condition of CTO was B3 A2 C2 (temperature of 60°C, material-to-solvent of 1:4g mL⁻¹ and extraction time of 3h) with the maximum oil yield (76.83%). The obtained CTO was non-drying oil with an iodine value of 14.69 g per 100 g, and lauric acid was the main component of 42.28%. Hydrogen peroxide scavenging activity of CTOE can reach 49.81% at 2.5mgmL⁻¹, while antioxidant activity (AA) on the oxidation of linoleic acid dropped from 56.82% to 31.70% during the first 80 min. CTOE could prevent HSA from oxidative damage induced by hydrogen peroxide by inhibiting the formation of protein carbonyl and increasing hydroperoxides

content effectively. Total phenolic content was 68 mg g⁻¹, and the epicatechin and catechin were 2.74 and 2.26 mg g⁻¹ in their phenolic compositions. These all-suggested CTO and CTOE might be new worthy exploiting functional sources.

Defatted coconut testa extracts showed high amounts of phytonutrients such as phenolics, flavonoids, and tocopherols and have been shown to possess antioxidant and hypolipidemic effects in experimental animals. Geetha et al. (2016) carried out rat feeding studies on the impact of ethanolic extracts from defatted coconut testa in experimental animals (C57BL/6). Feeding of testa extract at 50 and 100 mg/kg body weight showed increased body weight in high fat-fed animals when compared to starch fed control (SFD) group. Treatment with an ethanolic extract of coconut testa reduced their body weight dose-dependently. Lipid profiles like triglycerides, cholesterol, and LDL levels were significantly decreased, whereas HDL levels were increased, indicating its health beneficial effect (antiobesity effect). Catalase, SOD, GPx, TBARS in tissues, analysis of OGTT, serum insulin levels, advanced glycation, and atherogenic protection were augmented at different levels in the treated groups.

Analysis of serum showed increased HDL-C in the testa extract treated group and, therefore, higher protection against atherogenesis than the high-fat diet-fed group. Lesser fecal fat content and a higher level of liver cholesterol were observed in the high fat-fed group, and treatments with testa extract (rich in phenolics) ameliorated significantly. Fat content in the organs (liver, heart, kidney & adipose) of the HFD group was high. Furthermore, certain fatty acids observed in the tissues were 14:0, 16:0, 18:0, 18:1, 18:2, 20:0, 20:3, and 20:4, among which 14:0, 16:0 & 18:0 are the major saturated fatty acids that increased significantly in HFD when compared with the SFD group and ameliorated with testa extract (rich in phenolics) dose-dependently. Hence, coconut testa, a by-product of the coconut processing industries rich in natural phytonutrients, could be exploited to treat human diabetes and obesity conditions.

The utilization of coconut testa defatted flour in bakery products.

Sanjita Marasinghe et al. (2019) reported a study on the utilization of coconut testa defatted flour in place of wheat flour to prepare bakery products. For this purpose, coconut testa flour of four local

cultivars, namely san raman (SR), gonthembili (GT), ran thembili (RT), TallxTall (TxT) against the commercial hybrid (COM) grown in Sri Lanka were used in the study. A hundred grams of coconut testa flour produced from partially defatted coconut pairings was extracted with a 70% ethanol-water mixture. The TPC and FRAP assays were conducted using a 96 well microplate reader. Percentage yield (%) of crude extracts of SR, RT, GT, TXT, and COM were 8.26, 6.87, 7.66, 8.06, and 11.17, respectively. The maximum TPC content was observed in TXT (62.58 ± 5.99 mg GAE/g of extract), while the minimum TPC content was recorded for GT (27.53 ± 4.54 mg GAE/g of extract). The lowest FRAP value was observed for SR (0.26 ± 0.02 mmol FeSO₄/g of extract), while the highest FRAP value was observed for COM (0.67 ± 0.00 mmol FeSO₄/g of extract) variety. In conclusion, coconut testa flour is a rich source of phenolics and antioxidants.

The presence of these bioactives (from testa) in bakery products would make the testa a potential functional ingredient in the food processing industry.

Coconut testa in feed formulation.

A study by Nuha et al., 2019 aims to determine the coconut testa in the most effective feed formulation for red tilapia growth to provide a high survival rate. The treatment used was feed containing coconut testa A(0%), B(5%), C(10%), D(15%), and E(20%). The results showed that using 5% coconut testa in feed was effective for a growth rate of red tilapia because the response to feed was relatively faster, the highest survival rate was 92%, and the growth rate was 6,19g. The feed can fulfill the energy needs and help the growth of red tilapia because the range of nutrient content of pellets is in accordance with the fish needs.

Coconut testa with banana peels for organic waste management

Organic waste produced by economic activities may create health, aesthetic, and economic problems. One of the approaches applied to solve this problem is the utilization of decomposer macro fauna to decompose the waste. One of the decomposers with great potential is Black Soldier Fly larvae (*Hermetia illucens*), which can consume various types of organic manure and convert it into biomass with high protein and lipid content. In this study, banana peels and coconut testa had been fed to the larvae at 200 mg/larvae/day as the objects

that represented organic wastes with low fiber content and high fiber content, respectively (Putra et al. 2020). This study aimed to observe the growth and efficiency of BSF larvae in decomposing those wastes. The analysis was conducted on some parameters such as the growth and consumption rate, the efficiency of conversion of digested (ECD), waste reduction index, and mortality rate. The results showed that BSF larvae that consumed banana peel had a higher final weight (58.24mg), growth rate, and consumption rate, while the mortality rate was lower than BSF larvae that consumed coconut testa. The ECD of the larvae group that consumed banana peel was higher than the larvae group that consumed coconut testa. The waste reduction index of banana peel was higher than coconut testa (1.5 and 1.4, respectively). The larvae that consumed coconut testa had a longer pupation period (9 ± 1.75 days) than the larvae consumed banana peel. Based on this result, it can be concluded that the fiber content of organic waste affected the decomposition rate and growth of BSF larvae.

Coconut testa for preparation of value-added products

Solid-state fermentation (SSF) is an alternative low-cost useful process that has many vital applications in the field of biotechnology (Jamaluddin et al. (2016). In this study, SSF has been employed as a process for the production of value-added agricultural by-products using coconut testa (CT), rice bran (RB), and the combination of both substrates (CT-RB). The effect of SSF by *Monascus purpureus* on total phenolic content (TPC), antioxidant, anti-tyrosinase, and anti-elastase of the substrates were studied and compared with its non-fermented counter parts. The results showed that the SSF had improved the TPC up to three-fold higher in the studied substrates. Antioxidant potential evaluated using FRAP analysis also exhibited an enhancement in fermented substrates with the values ranging from 23.70 to 63.15 mg AAE/g sample. On the other hand, the radical scavenging activity evaluated using DPPH assay showed a different trend than the TPC and FRAP analyses. In other studies, tyrosinase and elastase inhibition activities were enhanced in most substrates upon the fermentation. The free phenolic acid content changes (p-coumaric, caffeic, ferulic, sinapic, vanillic, protocatechuic, gallic, and 4-hydroxy benzoic syringic acid) of the substrates after fungal fermentation was also examined through high-performance liquid chromatography (HPLC)

analysis. In summary, SSF offers a tool further to increase the bioactive potential of the studied substrate.

Other Uses of Coconut testa

The testa is currently being used in industry for the production of value-added products like biodiesel, edible oil, cosmetics, hair oil, pharmaceuticals and other allied industries.

Conclusion

Coconut testa is a by-product of the coconut oil/virgin coconut oil industry. About 18% of the coconut (copra and the wet coconut) equivalent to about 88,884 tonnes are removed as testa during pairing of coconut. The testa has about 50-68% oil which may be used for edible purposes and may add about 44,442 tonnes of coconut pairing/testa oil to the edible oil pool. Already a number of brands of testa oil viz. sadhya, GFO coco kera Tripathi, Kaveri, Keratreat, Navaruchi, Kera Mudra, etc., are commercially available under specific product approval. The full potential of the testa is to be explored and the oil and cake to be put to edible use for maximum benefits in terms of commerce and health.

The cake contains residual oil and health-beneficial compounds. Wet coconut testa has more tocopherols, tocotrienols, phenolics than dry coconut/copra testa. The oil may be included under the specification of coconut oil with suitable levels of iodine value, color, and fatty acid composition. As testa oils have higher amounts of unsaturated fatty acids and health-promoting compounds than normal coconut oil, the testa oil may provide more health benefits to consumers than normal coconut oil. The de-fatted testa and its extract may find application in preparing healthy foods, especially for diabetes and obesity-related population. More research on the antioxidant, antiviral, antimicrobial, and antidiabetic effects of testa oil and testa extracts, as well as related health benefits in humans, is needed so that the defatted testa can be used more effectively for health improvement, resulting in an increase in its commercial value.

Acknowledgements

The authors thank the Director, CSIR-CFTRI, Mysuru, for infrastructural facilities and Chairman, The Coconut Development Board (CDB), Kochi, for funding various projects on coconut at CSIR-CFTRI, Mysuru. ■