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Utilization Pattern of Banana Pseudostem - A Review

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Abstract

Banana (*Musa* sp.) is one of the important fruit crops grown almost in every state of India and ranks fourth in the world as a dietary staple food after rice, wheat and corn. Apart from the fruit, banana crop generates a huge quantity of biomass in the form of pseudostem, leaves, suckers etc. At present, this biomass particularly the pseudostem is an absolute waste in most of the states of India. The banana pseudostem is a thick stalk grows up from the ground and form the backbone of the herbaceous plant. The edible part of the banana stem is the inner portion of the fibrous stalk called as banana centre core. Banana stem is rich in fiber, potassium and vitamin B6 which aid in the treatment of ulcers and in the development of a sport drink, that together benefit the muscles and production of hemoglobin and insulin. In Ayurvedic practices, banana pseudostem is used in weight loss and is also said to be beneficial for overall health in terms of diuretic and to prevent kidney stones. There are reports on the traditional uses of banana stem juice for treating diarrhea, dysentery, diabetes and antioxidant actions. Banana centre core juice is well known remedy for urinary disorders, helps in the treatment for removal of stones in the kidney, gall bladder and prostate, in nervous disorders like epilepsy and hysteria. Several value added products *viz.,* fibre, yarn, fabrics, vermi compost, liquid fertilizer, quality papers, candy and pickles from banana pseudostem have been developed. Equipment package for post-harvest processing of banana pseudostem and central core *viz.,* banana central core slicer, dicer, fibre extraction unit, surface water removal, juicer / grinder and juice squeezer are available. The technology has been developed for minimal processing of banana central core and RTS beverage juice, candy and pickles from banana central core. Studies also have reported microbial fermentation of pseudostem core for bio-ethanol production.

Keywords: Banana pseudostem, Value addition, Value added products, Processing machineries

Banana (*Musa* sp.) is one of the important fruit crops grown almost in every state of India and ranks fourth in the world as a staple food after rice, wheat and corn. Total world production of banana is 139.90 million tons. India is the largest producer of banana (29.80 million tons) followed by china (10.60 million tons) Uganda (9.80 million tons), Philippines (9.20 million tons), Ecuador (7.6 million tons), Brazil (6.9 million tons) and Indonesia (6.2 million tons) (Food and Agriculture Organization, 2013).

There are two wild species of banana *viz., Musa acuminata* & *Musa balbisiana* and almost all the modern edible parthenocarpic bananas comes from these two species (Robinson & Sauco, 2010). The stem of the banana plant, which is also called as the pseudostem produces a single fruit bunch before dying and is replaced by a new shoots (Anhwange *et al.*, 2009). This crop generates a large amount of residue, despite each plant producing only one fruit bunch. After the harvest, the pseudostem is cut and usually left on the plantation or burnt, which could ultimately cause several environment issues (Cordeiro *et al.*, 2004). Thus, the utilization of the banana waste pseudostem has gained more attention in recent years. The pseudostem has been used as a material for making paper and forage (Buragohain *et al.*, 2010; Umaz *et al.,* 2005). More over, it has been reported that these waste materials are rich in minerals and nutrients, especially dietary fibre (Aziz *et al*., 2011). However, very little is known on the composition of the pseudostem and its drying properties; effects of drying on composition; quality of dried product or its utilization in food manufacture and the characterization of fibre components. The exploitation of banana pseudostem waste into products could significantly benefit the environment and increase its economic value.

The review is focused on the utilization pattern of banana pseudostem, its nutrient composition, physico-chemical properties of fibre components, value addition and value-added products from banana pseudostem. It also covers few reviews on microbial fermentation of banana pseudostem for value addition.

Banana Pseudostem

Apart from the fruit, banana crop generates a huge quantity of biomass in the form of pseudostem, leaves, suckers etc. At present, this biomass particularly the pseudostem is an absolute waste in most of the states of India. Not only this, but for disposing the pseudostem, presently farmers are spending about Rs.8000 to Rs.10000/ha (Anonymous, 2011). The banana pseudostem is a thick stalk grows up from the ground and form the backbone of the herbaceous plant. The edible part of the banana stem is the inner portion of the fibrous stalk called as banana centre core. Banana stem is rich in fibre, potassium and vitamin B6 which aid in the treatment of ulcers and in the development of a sport drink, which together benefits the muscles and production of hemoglobin and insulin. In Ayurvedic practices, banana pseudostem is used in weight loss and is also said to be beneficial for overall health in terms of diuretic and to prevent kidney stones (Chandrasekaran, 2012). There are reports on the traditional uses of banana stem juice for treating diarrhea, dysentery, diabetes (Ghani, 2003 & Yusuf *et al*., 2009), pain and snakebite (Coe & Anderson, 2005) and for antioxidant actions (Krishnan, 2005). Banana stem juice has been reported to have excellent therapeutic efficacy such as dissolving the pre-formed stones and preventing stones in urinary bladder (Kailash & Varalakshmi, 1992 and Kailash *et al*., 1993). Banana centre core juice is well known remedy for urinary disorders, helps in the treatment for removal of stones in the kidney, gall bladder and prostate, in nervous disorders like epilepsy and hysteria (Carine *et al.,* 2006). Different value added products *viz.,* fibre, yarn, fabrics, vermi compost, liquid fertilizer, quality papers, candy and pickles have been developed from banana pseudostem (Anonymous, 2012). Equipments for post-harvest processing of banana pseudostem and central core *viz.,* banana central core slicer, dicer, fibre extraction unit, surface water removal, juicer/grinder, juice squeezer and technology for minimal processing of banana central core, RTS beverage juice, candy and pickles from central core are available (Anonymous, 2011).

Components of Banana Pseudostem

The different components of banana pseudostem *viz.,* hard fibre, soft fibre and central core as shown in Fig. 2a. The pseudostem is normally 5 to 7.6 meters tall (varies from species to species) growing from a rhizome (Nelson *et al*., 2006). The tender core (Fig. 2b) inside the pseudostems carries the immature inflorescence, which eventually emerges at the top. Therefore, most of the nutrients of the pseudostem are present in the tender core. Banana pseudostem (Fig. 1) is the stem of banana plant and it produces a single fruit bunch before dying and then is replaced by new shoots (Anhwange *et al*., 2009). Since each plant produces only one bunch of bananas and cannot be used for ratooning, harvesting of banana generates a large amount of residue (Cordeiro *et al*., 2004). It has been reported that banana is the second largest producer of fruit in terms of quantity, contributing about 16 per cent of the world's total fruit production (Mohapatra *et al*., 2010). Therefore, every year after harvesting, a large amount of bare pseudostem is cut

Fig. 1: Banana pseudostem and its central core (covers with soft and hard fibre sheaths)

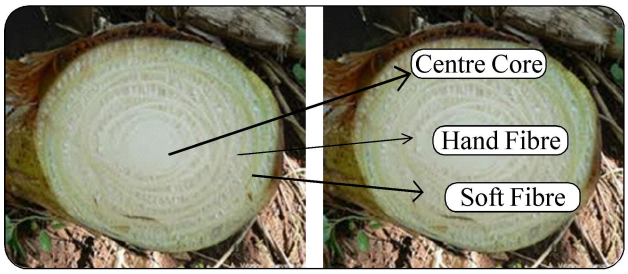

Fig. 2a : Components of banana pseudostem

Fig. 2b : Banana pseudostem tender and hard centre core

and left behind as waste worldwide, which ultimately leads to generation of waste and rotting of pseudostem can contaminate water resources that affects the environment and health of living micro organisms (Aziz *et al*., 2011 & Hossain *et al.*, 2011). Pseudostem contributes to major biomass of banana plant and it has limited commercial value and is considered as an agricultural waste (Padam *et al*., 2014).

Pseudostem Central Core

Banana pseudostem core is an inner most tender portion of pseudostem which is edible and used in preparation of candy, drinks and pickles (Mohiuddin, 2014). About 10 to 12 t/ha central core could be generated / ha and it is consumed as vegetable in some countries like Malaysia, India and Srilanka (Kennedy, 2009 & Subbaraya, 2006). It has several medicinal properties including antimicrobial property and pathogenesis protein (Baree *et al.,* 2000).

Navsari Agricultural University, Gujarat has standardized various processes protocols for developing edible products *viz.,* milk and chocolate coated candy, RTS and pickles from central core. The process protocol for developing candy has been standardized for pilot scale production. The product developed has been tested for its nutritional parameters at CFTRI, Mysore (Anonymous, 2009).

Mohapatra *et al.* (2010) reviewed on value addition to pseudostem core and reported that pseudostem core is used in preparation of many products such as jam, pickles, RTS beverages, flour *etc.* Fibres from pseudostem are used as natural absorbent and in bio-remediation agent for bacteria in natural water purifier. They are used as a substrate in mushroom cultivation. Other products like paper boards, tissue papers and many fibre based products are prepared from pseudostem.

Aziz *et al.* (2011) studied the chemical and functional property of tender core of pseudostem flour and reported that it consist of high moisture (8.82 %), fat (1.18 %), protein (3.52 %) and ash (10.08 %).

Banana Rhizome

Pseudo-stem and rhizome of banana plant together contribute 43.48 per cent of the biomass (Fig. 2c). Use of rhizome as seed material is highly discouraged due to inexpensive and adequate supply of disease free, high yielding tissue culture plantlets. In indigenous systems of medicine, pseudostem juice is a well-known remedy for urinary disorders, stomach troubles like diarrhea, dysentery, flatulence and also it helps in the treatment for removal of stones in the kidney, gall bladder and prostate which is also used as an antidote for snake-bite (Coe & Anderson, 2005 and Carine *et al.,* 2006). Pseudostem and rhizome are profusely used in Ayurveda and Unani system of medicines to cure both infectious and degenerative diseases. It has been reported by Justiz Smith *et al*. (2008) that the fibre of the banana pseudostem has a high young's modulus and water absorption capacity. Moreover, the banana pseudostem shows significantly physical properties such as relative tensile strength and

Fig. 2c : Pseudo-stem Rhizome

stiffness. The application of natural fibres including banana pseudostem has been proved promising in various technical field such as replacing synthetic fibres as reinforcement in various composites use in automobile parts (Pothan and Thomas, 2003). Banana vermi compost can a replacement for chemical fertilizers, nutrient spray and chemical spray, which ensures soil health (Phirke *et al.,* 2001). Due to largely availability of banana stem waste in the country, it is important to implement clean production and green chemical technology to utilize waste banana pseudo stem. Snehal *et al.* (2014) reported that India is amongst the largest banana (*Musa acuminate*) producing countries and thus banana pseudostem is commonly available as agricultural waste to be used as lingo cellulosic substrate.

Rhizome extracts were used as a coolant, to treat diabetes, piles, intestinal worms, mental diseases, acidity, food poisoning, to cure pyorrhea and to heal wounds. Despite rich nutritional and nutraceutical properties of pseudostem and rhizome, they are wasted and incinerated in India and elsewhere**.** Extensive literature survey also supported that no work has been reported regarding utilization of banana pseudostem and rhizome for food, nutraceutical or pharmaceutical purpose (Saravanan and Aradhya, 2011). Functional properties of pseudostem and rhizome of banana *Musa* Spp. VAR Nanjanagudu Rasbale has been published by Saravana (2015).

Nutritional Value of Banana Pseudostem

Banana pseudostem has a very high content of dietary fibre and has caught the attention of food scientists in recent years. It could be used more in food rather than in the feed industry. Aziz *et al.* (2011) and Bhaskar *et al.* (2011) have reported the proximate composition of banana pseudostem and are presented in Table 1 & 2.

Controversy of Nutritional Composition of Pseudostem

The proximate composition of pseudostem and central tender core as per the studies from Bhaskar *et al*., 2011 and Aziz *et al*., 2011 is given in Table 1 & 2 which is considerably different to each other. One possibility is that some of the nutrients were underestimated from the study of Bhaskar *et al.* (2011). For example, the ash value in the study was 0.3 per cent. In contrast, Ho *et al*. (2012) reported that the total ash was 6.8 per cent and mineral content including sodium, potassium, calcium, magnesium, phosphorus, iron, zinc and manganese was 3.1 per cent. The total mineral value detected by the study was even more than 0.3 per cent. Hence, it is reasonable to believe the ash measured in the study of Bhaskar *et al*. (2011) was under estimated. Another possibility is that the methods used in the two studies were different. The total carbohydrate obtained from the study of Bhaskar *et al.* (2011) was the sum of sugar, starch and dietary fibre, while the total carbohydrate was calculated as 100 per cent minus

TABLE 1

Proximate composition of banana pseudostem

Nutrients	Content (%)
Protein	2.5
Fat	1.7
Free sugar	3.4
Soluble dietary fibre	1.4
Insoluble dietary fibre	27.4
Starch	27.3
Ash	0.3
Moisture	15.1

Source: Bhaskar *et al*. (2011)

TABLE 2

Proximate composition of tender core of banana pseudostem flour

Nutrients	Content (%)
Moisture	8.8
Fat	1.2
Protein	3.5
Ash	10.1
Crude fibre	19.5
Total carbohydrate	56.9

Source: Aziz *et al.* (2011)

Note: All values are calculated on a dry weight basis

moisture, fat, protein, ash and crude fibre in the study of Aziz *et al*. (2011). The studies on the proximate nutrients of banana pseudostem are limited. Since carbohydrate is the main component of banana pseudostem, more accurate and detailed study need to be done on the carbohydrate composition to estimate the nutritional value of banana pseudostem. Other factors such as species, maturation stages and measurement methods may also influenced in the differences in the nutrient values of the banana pseudostem. For example, Saravanan and Aradhya (2011) claimed that total phenolic and total flavonoids in various solvent extracts of different banana pseudostem cultivars are different. The range may vary from 7.58 to 291 mg gallic acid equivalent and from 4 to 80 mg catechin equivalent, respectively.

Manimehalai *et al.* (2005) reported that moisture, protein, fat, minerals, fibre and carbohydrate content of pseudostem as 93.1, 0.3, 0.03, 1.04, 0.68 and 1.20 g/100 g, respectively. Similarly, the nutritive value of rhizome reported by Gopalan *et al*. (1989) which includes moisture, protein, fat, minerals, crude fibre, carbohydrates, calcium, phosphorus, iron, and energy of edible portion as 85.1, 0.4, 0.2, 1.4, 1.1, 11.8, 0.025, 0.010, 0.0011 g and 51 kcal/100 g, respectively. Rhizome is often cooked and eaten as a vegetable in India, mainly in tribal areas while, pseudostem is often cooked and eaten as a vegetable mainly used in curry preparation.

Manilal and Sony (2011) reported on composition of different layers of banana pseudostem sheath and detailed characteristics of fibres from physical and bio extraction methods. Cellulose, hemicellulose, lignin, pectin and ash were determined by chemical analysis of pseudostem sheaths. Lignocellulose constitutes about 60 - 85 per cent dry weight of the banana pseudostem sheath, in which cellulose accounts for about 50 per cent. Except for the minor changes in hemicellulose, lignin, and ash contents, the physical and bioextraction of fibers are comparable with their chemical and physical properties. Lengthy bio extraction may affect the fibre qualities. Scanning electron microscopy (SEM) studies showed clean and smooth surface of bioextracted fibres unlike in physically extracted ones.

Abdullah *et al.* (2014) reported that banana pseudostem and banana fruit-bunch-stem are agricultural residues that can be used for conversion to bio-char, bio oil, and gases by using thermo chemical process. The feasibility of the banana wastes as a feedstock for thermo chemical process in comparison with other biomass was also reported.

Banana plant bio-waste, pseudostem and rhizome serves as a potential source of multifunctional bioactive compounds and functional ingredient in food and other allied industries (Saravanan and Aradhya, 2011a). Based on the huge volume of bio-waste generated and its traditional medicinal use, it is worth exploiting as a source of natural bioactive compounds. In the study sequential extracts from banana pseudostem (BPS), rhizome (BR), and isolated compounds including chlorogenic acid, 4-epicyclomusalenone and cycloeucalenol acetate, were tested for their antimicrobial activity, anti-platelet aggregation and cytotoxicity. Isolated compounds and crude extracts exhibited strong antimicrobial activity against a wide range of bacterial and fungal strains, platelet aggregation induced by collagen and cytotoxicity towards human liver cancer (HepG2) cells.

Jun Ma (2015) reported details on banana pseudostem properties, nutritional composition which is used as food. In order to study the functionality of dietary fibre in the banana pseudostem, three methods were used and compared for determining the structure of dietary fibre, *viz.,* AOAC, NMR and GC methods. According to the result, cellulose was the main insoluble dietary fibre and pectin was the dominant soluble dietary fibre in the pseudostem. Throughout GC analysis, the neutral sugars that consisted of non-starch polysaccharides in the pseudostem were qualified and quantified. It has been identified that glucose, mannose and xylose were the main compounds in the pseudostem fibre. Commercial dietary fibre supplements (Metamucil) were compared with the pseudostem powder. The primary neutral sugars in the Metamucil were xylose, arabinose and mannose which were different from

that in the banana pseudostem and resulted in different functionality characters.

Okareh *et al*. (2015) reported the proximate and mineral composition of plantain wastes flour; a potential nutrient source in the formulation of animal feeds and results revealed that the wastes contained between 9.39 and 9.53g moisture, 1.87 and 19.37g crude protein, 0.73 and 1.83g crude fat, 8.10 and 15.50g crude fibre and 54.00 and 68.00g carbohydrate/100g sample. Plantain bract is very rich in iron (10.50 -14.00 mg), calcium (120.00 - 150.00mg) and phosphorus (110.00 - 180.00mg) / 100g sample. The plantain wastes could be source of nutrients in animal feed preparation, as they are high in protein, fibre and essential mineral content.

Minerals

The minerals of dried ground banana pseudostem are shown in Table 3. The mineral content will be affected by maturation stage, species and collection season and sample preparation (Ho *et al*., 2012 & Happi-Emaga

TABLE 3

Mineral contents of banana pseudostem

Minerals	Content (mg/100g dry sample)
Sodium	444.1
Potassium	944.1
Calcium	1335.3
Magnesium	255.0
Phosphorus	137.8
Iron	3.3
Zinc	8.1
Manganese	1.3

Source: Ho *et al.* (2012)

et al., 2007). As per Ho *et al*., 2012, the major minerals are Calcium (1335.3mg/100g), Potassium (944.1mg/100g), Sodium (444.1mg/100g). For instance, with the maturation of the banana pseudostem, the calcium concentrations will increase, while potassium will decrease, as a result the presence of more calcium in the tissues.

Jun Ma (2015) reported on the variation in proximate constituents of banana pseudostem by the influence of drying in cultivated varieties of *Musa balbisiana* and *Musa acuminate* as shown in Table 4.

TABLE 4

Effect of drying on the nutrient quality of banana Pseudostem cv. *Musa balbisiana*

	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Carbo hydrate (%)	Total
Musa balbisiana @ 40 C	6.2	3.1	3.2	12.9	66.3	91.7
BP 40B	5.0	3.2	4.0	12.3	66.2	90.7
Musa balbisiana @ 50 C	4.4	3.4	3.4	14.0	64.4	89.6
BP 50B	4.5	3.4	3.0	12.4	68.0	91.3
Musa acumunita	5.8	6.1	2.8	15.9	62.7	93.3

Apart from water, the pseudostem, contains several polymers such as cellulose, hemicellulose, pectin and lignin that constitute fibres with good mechanical properties. It has lesser amount of extractives, protein, starch and in organics. The best fibre of banana has been widely recognized for its good qualities over synthetic fibres and is used for making apparels, garments and home furnishing (Umaz *et al*., 2005). It is possible that these chemical compositions may vary with age, variety, climatic conditions, geographical location *etc*. Understanding the chemical composition and physical properties of the fibres is very important to utilize them properly in composites, textiles, pulp and paper manufacturing applications (Abdul Khalil *et al*., 2006 and Li *et al*., 2010).

Nowadays, banana pseudostem is widely used in animal feeding, clothing and paper industry. Buragohain *et al.* (2010) claimed that banana pseudostem could be used as an important staple food for pigs in banana producing areas. This could be used as feed material in both fresh and sun dried forms and both whole or chopped forms. Starch extracted from banana pseudostem could also be used to produce the glue

used in the manufacture of cartons. Banana pseudostem has been seen as a kind of vegetable in some countries. For example, in India and Malaysia, the fresh tender core of pseudostem is cooked and consumed, whereas the consumption of banana pseudostem as food in Australia is meager.

Work Carried out on Banana Pseudostem at CIRCOT, Mumbai and Navsari Agril. University, Gujarat

Processing of Banana Pseudostem

Presently, fibre extraction from pseudostem is being carried out mostly by hand extraction in villages of Tamil Nadu, Kerala, Karnataka, Andhra Pradesh and Maharashtra. The major drawback of this method is extremely poor fibre output (0.5 kg/day/man). In order to mechanize the fibre extraction from pseudostem, research was carried out mainly at CIRCOT, Mumbai (MS). They developed Raspador Machine which is used for extracting fibres from banana pseudostem easily and quickly (Fig. 3). Before extracting fibre using Raspador, one has to separate the sheaths from pseudostem by splitting it. The splitting of pseudostem is generally done by knife or koyta which is time consuming. For resolving this problem, NAU, Navsari has developed pseudostem cutter machine which facilitate speedy splitting of pseudostem in to 2 or 4 halves. From these halves, sheaths are separated easily. In general, splitting of pseudostem manually requires 2.65 minutes/100 kg as against 0.82 minutes /100 kg using pseudostem cutter machine. One such cutter machine is sufficient for providing sheaths required for four Raspador machines. Feriotti and Lguti (2012) proposed for use of banana pseudostem for value addition and stated that the pseudostem could be processed for mainly in handicrafts. Although studies have shown that the cellulose fibre has suitable features for industry, the yield is low because pseudostem has about 90 per cent of water.

Pseudostem Fibre Extraction Machineries and Processing

During 2008-09, the mechanized fibre extraction process at farmer's field conditions was standardized by Navsari Agricultural University with collaboration of CIRCOT, Mumbai. Additional pulley attachment for operating Raspador on power tiller or engine even in the absence of power supply. Bigger sized wheel attachments for easy mobility of Raspador under field conditions were standardized.

Based on the work done for first two years, the cost of fibre extraction from pseudostem was worked out. Considering the fibre yield and its selling price, farmers could realize an additional net income of Rs.23178/ ha. Apart from monetary benefits, fibre extraction technology also generates employment in rural areas.

Fig. 3: Fibre Extraction machineries and processing of pseudostem

During the process of fibre extraction, four components were obtained simultaneously. These components are fibre (about 600 kg/ha), Scutcher or residual pulp (30 to 35 t/ha), sap (15000 to 20000 l/ha) and central core (10 to 12 t/ha).

Fibre Based Products

Attempt was made by CIRCOT, Mumbai and MANTRA, Surat to prepare different fabrics from pseudostem and test their quality. Since banana fibres being coarse, it is not possible to spin these fibers on conventional spinning system. As the properties of banana fibres resemble to some extent with jute fibre, it was tried to spin the banana fibre on jute spinning system at Kolkata (WB). Through collaborative efforts of CIRCOT, Mumbai and NAU, Navsari so far 2.76 t banana fibre yarn has been prepared. The yarn samples were tested for quality parameters and based on the quality of yarn, different fabrics were prepared by MANTRA, Surat and CIRCOT, Mumbai. The fibre based product details prepared by both the partners are given in Table 5.

TABLE 5

Fibre based products developed by Mantra, Surat and Circot, Mumbai

Developed by	Products
MANTRA, Surat	Fabrics, synthetic based/ laminated fabrics,apparels prepared from fabrics
CIRCOT, Mumbai	Yarn, fabrics, non-woven fabric, micro crystalline cellulose (MCC)

Quality Grade Papers

The trials for optimization of bleaching and pulping conditions for preparing quality paper using banana fibre has been conducted by JK Paper Ltd., Songadh, Gujarat. The sheets of various grades (bleached and unbleached) have been prepared and their quality was tested by JK Paper, Songadh and CIRCOT, Mumbai. Paper prepared from fibre was found to have better quality than that paper prepared from whole pseudostem. Process for developing quality grade papers *viz.,* antigrease and check has been standardized. The banana fibre can be an alternative raw material to paper industry.

Handmade Paper and Board

Apart from quality paper at industrial scale, one handmade paper and board unit has been commissioned at NAU, Navsari (cap.: 100 kg/day). In this unit, variety of paper and board have been prepared using banana fibre, scutcher, cotton rags, waste paper and paddy straw in varying proportion. The quality of these papers has been tested at CIRCOT, Mumbai and reported in far about 1000 kg paper have been prepared. Using these paper and board, different articles like file cover, writing pad, art paper, printing paper, folder *etc*., have been prepared.

Handicrafts

Various handicrafts items have been prepared using banana fibres by Manav Kalyan Trust, Navsari. Handicrafts items include various types of decorative wall hangings, bags, dolls, key chains, *etc*. As a part of technology transfer, one training programme with respect to this has been imparted to women SHG, Chaswad.

Micro Crystalline Cellulose (MCC)

At CIRCOT, Mumbai has standardized the processing protocol for extracting MCC from banana fibre. The quality of MCC extracted from banana fibre is comparable with commercially available MCC. This suggests that MCC extracted from banana fibre could be used in pharmaceutical industries. Thus, banana fibre could be a viable alternative raw material for MCC. The techno-economic feasibility of using MCC extracted from banana fibre in pharmaceutical industry is in progress.

Scutcher Based Products

Vermicompost

Huge quantity of scutcher (about 30 to 35 t/ha) is generated during fibre extraction. In order to utilize this scutcher in a proper way, process for preparing

value added products has been standardized. At Navsari Agricultural University, process has been standardized for vermi compost preparation using pseudostem scutcher and dungs. Vermi compost with scutching waste: cowdung ratio of 70:30 was found to be an ideal in terms of nutrient content. One acre unit has been established at NAU farm and about 100 tonnes of vermi compost has been harvested. The vermi compost prepared has been tested for its quality and is being marketed in the NAU, under the trade name NAUROJI. In order to know its viability *vis-a-vis* FYM or bio compost (press mud based), cost of production of vermi compost was computed.

As Organics

Experiments as well as demonstrations have been conducted by NAU on farm and farmer's fields, respectively on various crops like sugarcane, banana, papaya, ginger, *etc*., using scutcher based vermi compost. Based on two years (2009-10 and 2010-11) of pooled results, it was concluded that pseudostem based vermi compost was found comparable with FYM and bio-compost in banana as well as sugarcane crop. Application of vermi compost at 3 kg/plant in banana and 5 t/ha in sugarcane in addition to RDF recorded, comparable yields of both the crops with FYM and bio-compost and use of vermi compost sustained soil health.

SAP

Particle board has been prepared using scutching waste by CIRCOT, Mumbai. Earlier reviews have indicated that sap was found to contain fair amount of nutrient in it. Navsari Agricultural University, Gujarat has been conducting experiments to test sap as liquid fertilizer and nutrient spray. About 15,000 to 20,000 litres of sap can be extracted from one hectare of pseudostem. NAU and CIRCOT have been developing technologies for using this sap in a profitable way.

Enriched Sap

The process for enrichment of sap is being standardized. Sap of about 2500 litres have been prepared and distributed among the farmers for demonstration. Apart from essential plant nutrient, it also contains growth promoting substances *viz*., GA and cytokinin.

Sap as Liquid Fertilizer

Sap extracted from pseudostem was evaluated as liquid fertilizer through field experiments for two years in crops like banana, papaya, sugarcane *etc*. The pooled results indicated that with the application of sap, saving of about 20 to 40 per cent RDF could be achieved without affecting the yields of banana and sugarcane. The rate of application of sap was at 3 l/plant and 5000 l/ha to banana and sugarcane, respectively.

Nutrient Spray Solution

Trials have been conducted using sap as a nutrient spray in vegetable nurseries (brinjal and chillies) under greenhouse condition. The results indicated that spraying of either enriched sap + vermi bed wash (1:1) on vegetable seedling resulted in achieving early transplantable stage by 8 to 10 days as compared to no spray.

As Mordant

At CIRCOT, Mumbai, trials were conducted for using sap as mordant in textile dying. Laboratory scale trial has been completed to test sap as mordant with natural dyes like *manjistha* and annatto. The test results have indicated good fastening properties of these dyes when used with sap. The process for using sap as mordant has been standardized at CIRCOT, Mumbai.

Value Addition to Pseudostem Central Core

Central core is inner most tender portion of the pseudostem which is edible. About 10 to 12 t/ha central core can be obtained. Navsari Agricultural University, Gujarat has standardized processes protocols for developing edible products *viz.,* candy (Fig. 4), RTS and pickles. Further, it has trained the farmers and women SHGs for preparing these products on a large scale. The process protocol for developing candy has been standardized and pilot scale production is in progress. The product developed has been tested for its nutritional parameters at CFTRI, Mysore. Until 2010, 48 kg candy of different quality and flavor has been prepared and distributed. This candy has an additional advantage as it contains iron and vitamin (A & B) in appreciable amount (Anonymous, 2009).

Milk coated candy

Chocolate coated candy

Fig. 4 : Milk coated and Chocolate coated candy from pseudostem core

Ready to Serve Drink (RTS Beverage) (Anonymous, 2011)

Pseudostem and rhizome of banana plant together contributes 43.48 per cent of the biomass. Pseudostem is a rich source of fibre, total carbohydrate and cellulose. Use of rhizome as seed material is highly discouraged due to the availability of inexpensive and adequate supply of disease free, high yielding tissue culture plantlets. In indigenous systems of medicine, pseudostem juice is a well known remedy for urinary disorders, stomach troubles like diarrhea, dysentery and flatulence and also it helps in treatment for removal of stones in the kidney, gall bladder, and prostate. It is also used as an antidote for snake bite. Rhizome extracts were used as a coolant, to treat diabetes, piles, intestinal worms, mental diseases, acidity, food poisoning, to cure pyorrhea and to heal wounds. Despite rich nutritional and nutraceutical properties of pseudostem and rhizome, they are wasted and incinerated in India and elsewhere**.** Extensive literature survey also supported that no work has been reported regarding utilization of banana pseudostem and rhizome for food, nutraceutical or pharmaceutical purpose. The soft drinks are being prepared from sugar syrup left out during candy preparation as well as directly from central core sap. The drinks prepared were fortified with flavours which have been standardized and certified of RTS (Fig. 5). At Navsari, a total of 78 litres of RTS has been sold during *Krishi Mela*, 2010 organized at NAU, Gujarat.

Banana rhizome juice

Banana pseudostem juice

Banana rhizome RTS beverages

Banana pseudostem RTS beverages

Fig. 5: RTS beverage juices from pseudostem and rhizome

Work Carried Out on Pseudostem at NRBC, Tiruchy

The ICAR - National Research Centre for Banana has significantly contributed for banana research and development. The Centre has developed many new technologies on improvement, production, protection, post-harvest management and value addition in banana. ICAR-NRCB has disseminated its new technologies to the farmers and entrepreneurs which have been adopted widely by the farming community. All the technologies and trainings have considerable impact on the improvement of rural economy by generating rural employment. National Research Centre for Banana at Tiruchy developed several following value added products from banana and were popularized and commercialized (CIAE/IEP/2015/06) (Anonymous, 2015).

- Juice, Bar, Jam and Sweet Chutney from pulp of ripe banana
- Flour, Baby food, Health drink, Sauce, Pickle and Chips from pulp of unripe banana
- Pickle from flower of banana
- Candy from centre core stem of banana
- Fibre from pseudostem sheath of banana

Use of Pseudostem traps for control of Weevils

Banana pseudostem trap @ 100/ha effectively controls banana weevils. Swabbing the cut surface of the traps with *Beauveria bassiana* or *Heterorhabditis indica* @ 20g trap-1 trapped the weevils and killed them instantly and they need not be collected (Fig 6).

Banana Weevils

Corm weevil, *Cosmopolites sordidus* and Stem weevil, *Odoiporus longicollis* are the key pests

Fig. 6: Banana pseudostem trap for Banana weevil

causing considerable damage. Yield loss to the extent of 10-30 per cent was recorded. If it is not checked it may be up to 100 per cent. The yield loss due to the pest varies depending on the stage of the crop at which the pest attacks the plant. Annual crop loss on a moderate scale would be 3.6 crores in Tamil Nadu alone.

Weevil Attraction

The host plant released volatile chemicals, which attracts the insects. Cut surface of pseudostem and corm emanates a host of volatile chemicals, which are chemically known as 'Plant kairomones', which attracts all Banana weevils. With the principle in mind, Banana pseudostem / corm trapping was conducted in areas endemic to Banana weevils in different parts of India (Sirumalai - Dindigul District., Maruthur - Karur District, Mutharasanallur - Trichy District, Kolli hills -Namakkal District, Mandya, Erasakanaikanur - Theni Districts of Tamil Nadu and Mahadevpura - Mandya - District, Karnataka).

Value Addition to Banana Pseudostem

CSIR-Central Food Technological Research Institute Mysore, has developed beverage blends from Banana pseudo-stem juice (Fig. 7). A process has been developed for the preparation of banana pseudostem juice overcoming the problem of browning. The palatability of the juice is increased by blending it with

Fig. 7 : Banana pseudostem blended beverages developed at CFTRI, Mysuru

other fruit juices or fruit juice concentrates. The product has a good shelf life and higher export potential due to the availability of the raw material in large quantities. The product could either be packed in glass bottles (about 3 months shelf life at room temperature) and for a longer shelf life aseptic cartons may be used. The product may also be packed in heat resistant PET bottles of food grade quality.

Ruthra Priya *et al.* (2014) evaluated different pre treatments *viz.,* citric acid (CA), ascorbic acid (AA) and potassium meta bisulphite (KMS) with varying concentrations (0.05, 0.1 and 0.2 %) and combinations were studied for standardizing the pre treatment method for minimal processing of central core of banana pseudostem. Based on the results of the investigation authors found that KMS at 0.2 per cent and combination of KMS (0.1 %) + AA (0.1 %) gave good result. The colour and pH was at acceptable level till 3rd day in ambient and 5 days in refrigerated temperature.

Krithika *et al*. (2015) studied the physio-chemical and phyto chemical composition of banana central core juice and juice powder. Authors conducted experiment on spray drying of central core juice using two different malto dextrin concentrations (0, 5 and 10 %) of the core material as encapsulating agent. Spray dried central core juice powders and fresh central juice were assessed for their physico chemical (pH, water activity, electrical conductivity and total soluble solids), phytochemical and micronutrient properties. Structures of the spray dried powders were studied with scanning

electron microscopy. Phytochemical screening of fresh juice and juice powder showed the presence of biologically important constituents-flavonoids and phenols. Hence, banana central juice powder could prevent significant post-harvest loss and in turn could be exploited to its fullest extent.

Saravanan and Aradhya (2011) reported on potential nutraceutical food beverage with antioxidant properties from banana plant bio-waste pseudostem (BPS) and rhizome (BR). In order to utilize these bio-wastes in a bioactive perspective, nutritional and nutraceutical components were studied from the juices and its Ready-To-Serve (RTS) beverage. Strong positive correlations were observed between TPC and TFC of BPS and BR juice with AOA assays. Among the different concentrations of RTS beverages prepared, 25 per cent BPS juice and 20 per cent BR juice with 15^0 brix TSS and 0.3 per cent acidity were adjudged as best by sensory panelists. Thus, BPS and BR juice could be effectively used to produce new generation functional beverages.

Bornar and Sumaiya (2015) developed healthy and therapeutic ready-to-serve beverage with different proportions of pseudostem juice and papaya pulp *viz.,* C [0:100], V1 [50:50], V2 [75:25] and V3 [85:15]. The best blend was selected by using 9 point hedonic scale *i.e*., V1 [50:50]. RTS was prepared as per FPO specifications. Storage studies were carried out up to 90 days for various physico chemical parameters including moisture content, ash content, pH, acidity, total soluble solids [TSS], turbidity, brix acid ratio with color and viscosity measurement. Authors concluded that the best blended ratio of pseudostem core juice and papaya juice was 50:50 for obtaining quality blended pseudostem RTS juice.

Vigneswaran *et al*. (2015) reviewed on banana fibre, scope and value-added product development and authors reported that banana fibre is a natural best fibre which has wide range of uses in hand craft product developments such as mat, rope, twines but only 10 per cent of the pseudostem is being used for making products and remaining is waste or used as fertilizer. As it has properties like weather proof, UV protection, moisture absorption, antioxidant and biodegradable, it could be used to make variety of products that help farmers economically and have wide scope to create new market. Recent studies have indicated that banana fibres possess a lot of advantageous in terms of physical and chemical properties which could be used as a very good raw material for the textile and packaging industry.

Studies on Fermentation of Banana Pseudostem

Noor Azwani and Azhar (2014) studied the production of lactic acid by using mixed culture of facultative anaerobic bacteria and banana pseudostem waste and reported that it could be used as substrate in producing lactic acid production.

Dabhi *et al*. (2014) studied the degradation of banana waste using bacterial consortium under solid state fermentation for cellulase production. The four bacterial strains were tested to find their ability to produce cellulases, which catalyze the degradation of cellulose, which is a linear polymer made of glucose subunits linked by 1, 4 glycosidic bonds. According to Souza *et al.* (2010) for every ton of banana fruit harvested around 4 tons of pseudostem remain at the harvest location undergoing natural degradation. Making use of this biomass for the production of alcohol, for fuel could be very attractive alternative by not only contributing to the preservation of the environment through removing this waste from the land but also by adding value to the fruit production matrix, transforming the residue into a commodity.

Elias *et al*. (2014) investigated the production of bio ethanol by *Saccharomyces cereviseae* using banana pseudostem residue as a fermentation substrate. The fermentation of pseudostem juice after concentrating to RS d≤ 62.1 g/L, resulted in an ethanol production of 22.1 ± 0.8 g/L with respective values of YP/RS = 0.47 ± 0.03 g/g, ethanol productivity (QP) 1.83 ± 0.12 g/L and effectiveness of alcoholic fermentation (EP) 80.4 ± 0.12 per cent.

Chien-Yih Lin *et al.* (2015) investigated the feasibility of converting banana pseudostem fibre into bio ethanol by acid pre treatment conditions and fermentation by

yeast. This study optimized the conditions for hydrolyzing banana pseudostem with sulfuric acid pretreatment process and selected a best strain of yeast (*Saccharomyces cerevisiae*) for fibre hydrolysate fermentation.

Ray and Ghatak (2013) reported on phytochemical characterization and antimicrobial property of banana pseudostem juice. Phytochemical screening revealed the presence of different minerals, tannins and Pseudostem extract / juice exhibited the strongest antimicrobial effect against *Staphylococcus aureus* and also other bacterial strains. Snehal Ingale *et al*. (2014) studied on exploitation of banana pseudostem as a source for bio ethanol production using two fungal strains *Aspergillus ellipticus* and *Aspergillus fumigates*. Fermentation of cellulosic hydrolysate (4.1g %) gave maximum ethanol (17.1 g/L) with yield (84 %) and productivity (0.024 g %/h) after 72 h.

The edible part of the banana pseudostem is the inner portion of the fibrous stalk called as banana centre core and it is rich in fibre, potassium and vitamin B6 which aid in the treatment of ulcers and in the development of a sport drink. There are reports on development of different value-added products *viz.,* fibre, yarn, fabrics, vermi compost, liquid fertilizer, quality papers, RTS beverage juice, candy and pickles from banana pseudostem core. The Central Institute of Agricultural Engineering, Coimbatore centre has developed equipment package for post-harvest processing of banana pseudostem and central core *viz.,* banana central core slicer, dicer, fibre extraction unit, surface water removal, juicer /grinder, juice squeezer. The technology for minimal processing of banana central core and RTS beverage juice, candy and pickles from central core has been standardized.

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