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Review Article

Usefulness of Banana (*Musa paradisiaca*) Wastes in Manufacturing of Bio-products: A Review

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Abstract

Banana (*Musa paradisiaca*) is one of the most important gigantic and oldest cultivated fruit crops grown almost everywhere in Bangladesh. Presently, the banana pseudostem is hazardous waste in Bangladesh whilst it has been used in several countries to develop important bio-products such as fibre to make yarn, fabric, apparel as well as fertilizer, fish feed, bio-chemicals, paper, handicrafts, pickles, candy, etc. Looking at this perspective, entrepreneurs of Bangladesh should take this golden opportunity and do the needful for such kind of business. The land of our country is suitable for banana production. Its fruit is a healthy diet and demandable in local markets as well as the free waste could be utilized to produce such bio-products which will contribute directly in our national economy. Thus, farmers or entrepreneurs should cultivate more banana trees in unproductive lands of coastal and hilly areas for extra income from the useless wastes and ensure eco-friendly environment. Women can also be employed in production of different bio-products from banana wastes and thus, they can contribute to their livelihood improvement. In conclusion, this review on banana waste utilization will be of help to the farmers, entrepreneurs, planners, scientists as well as Bangladesh government to take proper initiatives in socioeconomic improvement of Bangladesh.

Keywords: Pseudostem, bio-products, employment, eco-friendly, health care

1. Introduction

Banana (*Musa paradisiaca*, family Musaceae) is a central fruit crop of the tropical and subtropical regions of the world grown on about 8.8 million hectares (Mohapatra *et al*., 2010). It is possibly the world's oldest cultivated crop (Kumar *et al*., 2012). As a diet, banana is an affluent source of carbohydrate with calorific value of 67 calories per 100g fruit and is one of the most well-liked and widely traded fruits across the world (Emaga *et al*., 2008; Kumar *et al*., 2012). It is one of the tallest herbaceous plants with a pseudostem. Its tough treelike pliable stem is composed of the sheathing twisting leaf bases, which contains fibres of sufficient strengths to keep the tree upright. In different countries, about 300 varieties of bananas are grown, of which a vast majority are grown in tropical Asia (Simmonds, 1962). Banana grows almost everywhere in Bangladesh round the year. However, the foremost banana growing areas are Rangamati, Barisal, Rangpur, Dinajpur, Noakhali, Faridpur, Tangail and Khulna. The common species have been growing in Bangladesh are *Musa cavendishi*, *M. oranta* (Sagar kala), *M. paradisiaca* sub-species *paradisiaca* (Kancha kala), *M. paradisiaca* sub-species *sapientum*

(Kala), and *M. sapientum* sub-species *sylvestris* (Aita kala) (banglapedia). All varieties of banana can be used for the fibre extraction purpose (Mukhopadhay *et al*., 2008). *Musa textilis* (Pahari kala), a wild banana variety grown in Bangladesh, is important for good quality fibre (banglapedia).

Banana is mainly cultivated for it's ripen fruits, cooked vegetables and leaves in India and many other countries including Bangladesh (Khanum *et al*., 2000). It is the second largest produced fruit after citrus, contributing about 16% of the world's total fruit production (FAO, 2009). Banana is highly nutritious (Sharrock and Lustry, 2000) and is more easily digestible than many other fruits including apple (Mohapatra *et al*., 2010).

In spite of these various use of the banana plant, it is seen that huge portion of banana plants are just dumped as waste causing environment hazards and making ecosystem imbalance. Currently, millions of tones of banana pseudostem are dumped in our country as waste and most of the farmers are facing huge troubles in disposing the accumulated banana pseudostem. Therefore, an effective economic means of reducing this environmental problem by extraction of fibre and production of many essential food products, fertilizer, bio-chemicals, papers, etc. from banana waste (pseudostem) can be proposed.

2. Characteristics of banana fibre

The physical and chemical properties of banana fibre are considered below:

- The chemical composition of banana fibre is cellulose (50-60%), hemicelluloses (25-30%), pectin (3-5%), lignin (12-18%), water soluble materials (2-3%), fat and wax (3-5%) and ash (1-1.5%) (http://www.li-fei.com/products/4/e2.htm) (Mukhopadhay *et al*., 2008).
- Its appearance is similar to that of bamboo and ramie fibre; however banana fibre has better fineness and spin ability. It has shiny appearance depending upon the extraction and spinning process (Rao and Mohana, 2007).
- It has very strong fibre with 3% elongation and light weight.
- Its average fineness is 2386 Nm, average strength is 3.93 cN/dtex and average length is 50 ~ 60 mm (or 38mm) (http://www.li-fei.com/banana.htm).
- It absorbs and releases moisture easily.
- It can be spun by different methods like ring spinning, open-end spinning, bast fibre spinning, and semi-worsted spinning.
- It is bio-degradable and has no negative effect on environment and thus can be categorized as eco-friend fibre (Mukhopadhay *et al*., 2008).

3. Business Idea

Banana wastes are being used in different countries like India, Nepal and Philippines as an excellent business idea. These countries have been developing interesting products for last two decades and have been trying to replace cotton that is more expensive at market value. As a developing country, Bangladesh should begin such kind of business since the land of our country is suitable for banana production. Besides, farmers will be interested to cultivate banana for extra income from useless waste. We have huge barren land that can be productive due to the demand of raw materials of this business through the plantation of banana. If the pseudostem can be utilized for fibre extraction, it will create lots of employment opportunities and make rural woman and school dropouts empowered and improve their socio-economic level and standard of living.

In this proposal, attempt has been taken to build up a combination among research and trade system suitable for our country and sector-wise product (Fig. 1) manufacturing as well as business idea using banana pseudostem derived products in Bangladesh.

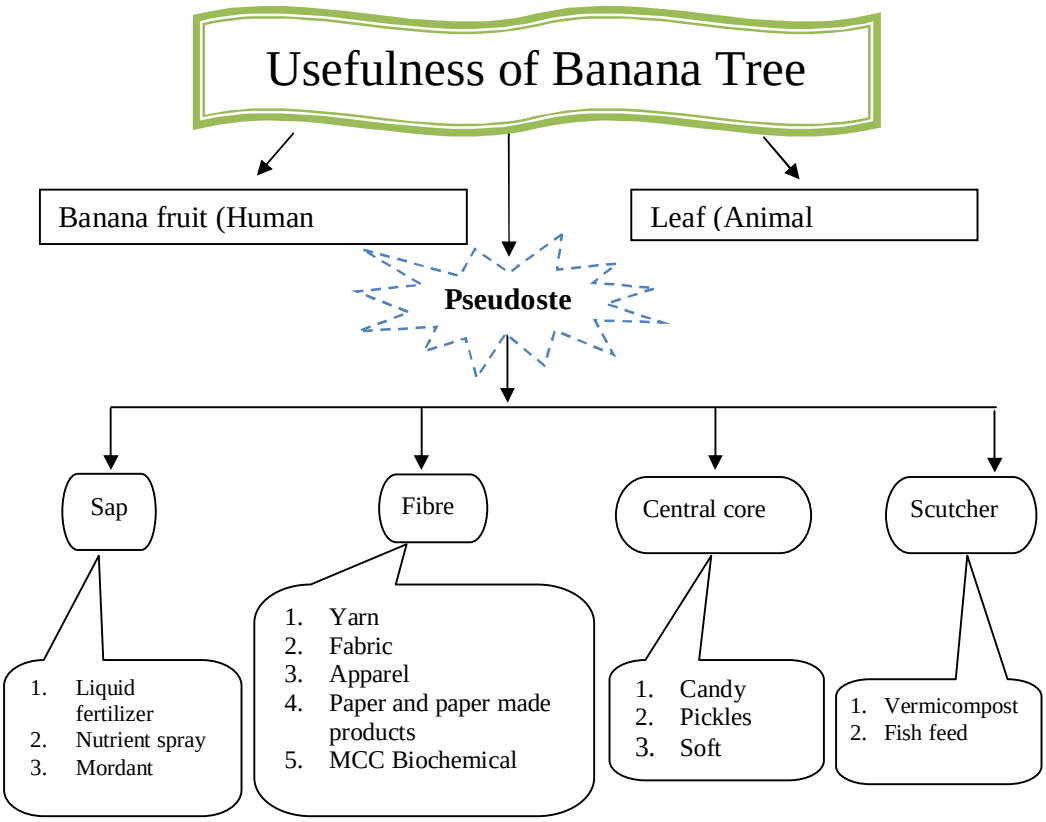

Fig. 1. Useful products made from banana waste (pseudostem)

4. Usefulness of Banana Waste

4.1. Pseudostem processing and fibre extraction

The banana fibre can be extracted manually or by machine. Manual fibre extraction is a cumbersome process. In this process, pseudostem is initially cut into pieces of about 60cm length and 7.5cm width. Then the pseudostem is scraped and the fibre is separated by using scraper or a flat blunt blade. In manual process, a skilled labour can produce only 500-600g of dry fibre in 8 hours time. On the other hand, fibre extraction process by machine can be carried out using cutter machine which facilitates speedy splitting of pseudostem into 2 or 4 halves. From these halves, sheaths are separated easily. Such cutter machine is sufficient for providing sheaths required for four raspador machines (Patil and Kolambe, 2011). By this machinery process, pseudostems are isolated from banana tree and divided into pieces. Then the pieces are passed through the extracting machine, known as mechanical decorticator and fibres are automatically extracted faster.

The mechanical decorticator contains of a pair of feed rollers and a beater (Mukhopadhay *et al*., 2008). After extraction by this technique, the fibres are dipped into bio enzymes to clean and improve quality in terms of length and softness, strength and colour which finally make the fibres shiny (Manandhar, 2010). After sun dry, the

fibres are ready for knotting. A bunch of fibres are mounted or clamped on a stick to facilitate segregation. Each fibre is separated according to fibre sizes and is grouped accordingly. To knot the fibre, each fibre is separated and knotted to the end of another manually. The separation and knotting is repeated until bunches of un-knotted fibres are finished to form a long continuous strand. This fibre can now be used for making various bio-products (Fig. 1).

4.2. Products from banana-pseudostem fibre

Banana fibre is extensively used as blending material in textile industry in countries like Philippines, Malaysia, Japan and Korea. It can be easily blended with other fibres such as jute and mesta being natural fibres. Therefore, lots of industrial products like gunny bags, door mats, carpets, yarn, ropes, geo-textiles, trivialities, luggage carriers and interior decorative crafts paper, tissue paper, paper bag, etc. can be made from this fibre, where great strength is required. It has also some industrial uses such as natural sorbent, as a base material for bioremediation and recycling and as a natural water purifier (Mohapatra *et al*., 2010). Among other uses banana fibre is used in making socks and gloves in European countries.

4.2.1. Yarn

Rope making from extracted banana fibre is called Banana fibre yarn (Fig. 2). Rope making is one of the most basic skills for converting any linear material into a usable stage (Manandhar, 2010). Rope is a length of fibres, twisted or braided together to improve strength, for pulling and connecting. It has tensile strength but is too flexible to provide compressive strength (Maleque *et al.*, 2007). There are actually three layers in the decaying bark of the banana tree. The outer layer is the toughest and usually used for weaving items. The middle layer produces rope that is used for thick cloth making and the inner layer which is the silkiest fibres is used for spinning yarns and making fine clothing (Mohapatra *et al*., 2010) such as sharee, three pieces, T- shirt, under garments, etc. (Figures 2 and 3) (www.Agricultureinformation.com).

4.2.2. Fabric and apparel

Cloths produced from rope or yarn is called fabric whilst various types of dresses made of cloths are called apparel (Sapuan and Maleque, 2005). The process of fabric and apparel production from banana fibre is as usual as cotton textile. It is also possible to prepare synthetic and laminated fabric by mixing some other fibre like jute or cotton in special ratio (Fig. 3).

4.2.3. Paper

Banana fibre can be an alternative raw material of paper industries like writing paper, anti grease paper, cheque paper as well as hard board industries (Fig. 4) (Muraleedharan and Perumal, 2010; Mohapatra *et al*., 2010 and Cordeiro *et al*., 2004). At first, raw paper materials are collected from banana plants and fibres are collected afterwards. The collected fibres are soaked in water prior to make pulp. Later, the extracted fibre is bleached by microbial treatment using *Trichoderma* and *Pythium* for 3-5 days (Muraleedharan and Perumal, 2010). These fungi acts on cellulose and breaks the bonds between lingo cellulosic complex structures and lignin and hemicelluloses are broken down and leached out (Crouch *et al*., 1998). It enhances the brightness of the paper and helps to soften the fibre as well as do pulping process easier.

After the microbial treatment, banana fibre has to be washed to clean unwanted materials including microbes and convert to pulp in a process called beating. All of the additives in required amount and actual proportions must add during the beating process. Usually starch, polysaccharide resins, and natural gums (glue) are used to modify or enhance the bonding between the fibres in paper pulp. In the sizing step it is tried to retard the ability of wetting and penetration. Sizing reduces porosity and hence reduces absorption ability. After several steps to be carried out finished paper is made from pulp

(Cordeiro *et al*., 2004). This paper is used to prepare shopping bags, files, visiting card, greeting card, invitation cover, scribing pad, envelops, art paper, printing paper, etc. (Uma *et al*., 2005; Muraleedharan and Perumal, 2010). Besides, writing paper is also prepared from banana fibre following as usual industrial process just by replacing banana fibre pulp against bamboo or wooden pulp (Uma *et al*., 2005 and Mohapatra *et al*., 2010).

Yarn from inner layer	Yarn from middle layer	Yarn from outer layer

Fig. 2. Production of yarn from banana fibres. (www.Agricultureinformation.com)

Saree	Shirt	Female's dress	Night dress
Coaster	Table mat	Stylish hand bag	Shopping bag
Laminated fabric	Laminated fabric	Normal fabric	Eco Shopping bag

Fig. 3. Different useable products made from banana fibres
(Source: www.Agricultureinformation.com)

Cheque paper	Anti grease paper	Banana fibre paper

Fig. 4. Paper products made from banana fibres (Source: www.Agricultureinformation.com)

Banana fibre board	Paper made products	Fibre made rope	Fibre made products

Fig. 5: Fibre board and paper made products from banana fibres (www.Agricultureinformation.com)

4.2.4. Hard board making

Hard paper and boards are made from banana fibre in combination with scutcher, cotton rags, waste paper and paddy straw in varying proportion (Mohapatra *et al.*, 2010) (Fig. 5). This type of board is being used in different ways in stead of existing board available in the market.

4.2.5. Handicrafts

Various handicraft items are prepared using banana fibre (Mohapatra *et al.*, 2010 and Manandhar, 2010). It includes various types of decorative wall hangings, bags, coaster, table mat, pillow, jajim, tosok, sofa sets, dolls, key chains, etc. (Fig. 5). Especially, women can be involved in this sector to improve their economic and social conditions (Patil and Kolambe, 2011).

4.2.6. Eco-bag

Environmentally degradable bag (eco-bag) can be made from banana fibre (Mohapatra *et al.*, 2010). This eco-bag with mixture of banana fibre and cotton is sturdy, wrinkle-resistant, and absorbent-resistant compared to bag with only cotton. Various designs and colour patterns are imposed to improve quality of eco-bag (Fig. 5).

4.2.7. Microcrystalline cellulose (MCC)

MCC extracted from banana fibre can be made for industrial purpose. It is used in pharmaceutical industries. It has huge application not only in pharmaceuticals but also in bakery, beverages, animal health products, etc. (Oliveiro *et al.*, 2007).

4.2.8. Central core based products

It is a matter of marvel that central core of banana tree is the inner tenderest portion of the pseudostem which is safe to eat. Various edible products *viz.*, candy, drinks and pickles are made from it (Aurore *et al.*, 2009).

4.2.9. Candy

The process for developing candy has been standardized and its nutritional values were tested. Different flavour is added to improve its

quality (Fig. 6). This candy has an additional advantage since it contains Fe and vitamin B in appreciable amount (Patil and Kolambe, 2011).

4.2.10. Drinks

Not only candy but also one kind of soft drink is being prepared from sugar syrup that is left out during candy preparation as well as directly from central core sap (Fig. 6). These prepared drinks are fortified with flavours which have been standardized by Patil and Kolambe (2011) for human consumption (Mohapatra *et al.*, 2010).

4.2.11. Pickles

By blending of central core, another item e.g. pickle can be made successfully with fruits and vegetables (Fig. 6). Shelf life study has been completed and quality testing is under progress (Patil and Kolambe, 2011).

4.3. Scutcher based products

4.3.1. Vermicompost

During fibre extraction from banana pseudostem, huge quantity of scutcher (about 30 to 35 t/ha) is generated. This scutcher is being converted to natural products like vermicompost by adding other essential components in order to value addition in proper way (Fig. 7) (Oliveira *et al.*, 2007 and Phirke *et al.*, 2001). Process has been standardized for vermicompost preparation using pseudostem scutcher along with dung in ratio of 70:30 (Patil and Kolambe, 2011).

4.3.2. As organic fertilizer

Vermicompost can be applied to crop fields as organic fertilizer (Phirke *et al.*, 2001). Experiments as well as demonstrations are being conducted at research farm and farmers' fields, respectively on various crops like sugarcane, banana, papaya, ginger etc. using scutcher based vermicompost. Effects of vermicompost has been found comparable with that of biocompost in banana as well as in sugarcane and this can sustain soil health of crop field (Patil and Kolambe, 2011).

4.3.3. As a fish feed

Vermicompost can be used as fish feed through blending. As a result, it reduces the cost of fish feed as well as decreases the dearth of local demand (Patil and Kolambe, 2011).

4.4. Sap based products

Sap can be utilized to prepare liquid fertilizer and nutrient spray solution which is extracted from pseudostem of banana fibre (Fig. 7). Several researchers have indicated that sap has fair amount of nutrient as Table 1.

4.4.1. Enriched sap

Enriched sap is nothing but fresh sap with essential plant nutrients as well as growth promoting substances viz. gibbrelic acid (GA) and cytokinin which can be an alternative for plants vegetative growth (Patil and Kolambe, 2011).

4.4.2. Liquid fertilizer

Banana sap extracted from pseudostem can be used as liquid fertilizer for banana, papaya, sugarcane, etc. Studies indicate that it may save 20-40% fertilizer. It also improves the yields of banana and sugarcane (Patil and Kolambe, 2011).

Table 1. Sap types and its nutrient composition

Sap type	Composition (ppm)		
	Nitrogen (N)	Phosphorus (p)	Potassium (k)
Fresh sap	4.2	35.1	1223
Enriched sap	119	50.4	1289

(Source: Patil and Kolambe, 2011)

Milk coated candy	Chocolate coated candy	Pickles	RSD (drinks)

Fig. 6: Edible products are made from banana waste. (Source: www.Agricultureinformation.com)

Spray in vegetable field.	Nutrient spray to mango tree	Dyed fabric with sap

Fig. 7: Different bio-products are made from banana waste (Source: Patil and Kolambe, 2011)

4.4.3. Nutrient spray solution (NSS)

NSS can be used as a nutrient in vegetable nurseries under green house condition (Fig. 7). Spraying of enriched sap in combination with vermibed wash (1:1) on vegetable seedling resulted in achieving early transplantable stage by 8 to 10 days as compared to no spray. Another experiment showed that spraying of both sap and vermibed wash together (1:1) resulted in higher fruit setting in mango (6.59%) as compared to control (4.62%) (Patil and Kolambe, 2011).

4.4.4. Mordant

Laboratory trial has been conducted to test sap as mordant with natural dyes which indicated good fastening properties of these dyes when used with sap (Fig. 7). The process for using sap as mordant has been standardized by Patil and Kolambe (2011).

5. Market potential

The above review reveals the market potential of banana fibre and its products. There are sufficient raw materials with scope to increase more as the soil of Bangladesh is suitable for banana tree cultivation (Islam and Hoque, 2005). It is known that the global price of cotton is escalating gradually every year. On the other hand, almost 96-97% cotton is imported from foreign countries every year in Bangladesh. It needs 18 thousands core taka per annum. So it is important to explore the different natural fibre sources to overcome this crisis. Besides, the banana tree, except its fruit, is totally useless and it is considered as waste. The potentiality of banana fibre to partially replace the consumption of cotton and jute fibre in many countries has already been explored (Patil and Kolambe, 2011and Mohapatra *et al.*, 2010). The garment products, paper and paper products,

vermicompost, food items using central core of banana tree, natural dying mordant as well as handicrafts have high demand in local market. These items will be cheaper than same other products in the market if these can be produced from materials like banana fibre.

It is right time to train up as well as share and gather knowledge from pioneers. If it is possible to implement these techniques in Bangladesh it would be possible to establish many industries only from banana tree waste like: textile industry (yarn, fabric, apparel, sharee, baby pampers, hygiene pad), paper mill: writing paper, tissue paper, paper bag, paper made products (cards, notebooks, table calendar, paper box etc.), bio-fertilizer industry (vermicompost, nutrient spray), fish feed industry, dyeing industry, pharmaceuticals, food processing industry (candy, pickles, soft drinks), handicrafts and bed requirements (Khanum *et al.*, 2000; Phirke *et al.*, 2001; Cordeiro *et al.*, 2004 and Uma *et al.*, 2005).

6. Environmental and Social Impact

Banana fibre could play a vital role in emerging bio-economy. Currently, millions of tones of banana pseudostem are dumped as waste and most of the farmers are facing huge problems in disposing the accumulated banana pseudostem. Therefore, an effective and economic means of reducing the environmental problem by extraction of fibre from pseudostem and production of valuable bio-products from it is crucial. All varieties of banana can be used for the fibre extraction purpose (Mahapatra *et al.*, 2010). Banana fibers are completely bio-degradable, recyclable and are more environment friendly than synthetic fibers both in terms of production and their disposal (Mukhopadhay *et al*., 2008). Therefore, the banana products have export potential. Unlike synthetic fibers which are largely produced from non-renewable resources, banana fibers are made of renewable resources.

In addition to fibre extraction, pseudostem can be recycled to be used as biofertilizer and are found to be highly useful and economic for banana growers (Mukhopadhay *et al*., 2008). Also, the wastes produced during processing of banana fibres are mainly organic wastes and residues that can be further processed to generate electricity or make ecological housing material (MOT, 2010). Banana fibers are carbon neutral; they absorb the same amount of carbon dioxide that they produce (Muraleedharan and Perumal, 2010). In addition, conventional raw material of paper production like bamboo or wood chips obtained from falling trees increases global warming. More over in this method required chemicals releases toxic substances that cause environmental pollution resulting in the need for treatment of water. Banana waste utilization will overcome these environmental hazards (Muraleedharan and Perumal, 2010 and Mahapatra *et al*., 2010).

6.1. Employment

Pseudostem based domestic industry could overcome unemployment problems to some extent. Especially, women can play a vital role in this sector and increase their family income. The banana fibre industry could provide employment to millions of people, largely small scale (marginal) farmers and processors. Income from the industry could contribute significantly to the income and food security of the poor farmers and workers in fibre industries (Frison and Sharrock, 1999). It will enhance the interest to the self help group and entrepreneurs.

6.2. Human and soil health care

Banana and banana pseudostem contains herbal medicinal properties to human (Kumar *et al.*, 2012) including pathogenesis protein and antimicrobial properties (Baree *et al.*, 2000). Moreover, pickles, candy and soft drinks produced from banana waste were found healthier (Muraleedharan and Perumal, 2010). On the other hand, banana pseudostem waste provides natural ventilation in soil. Banana vermicompost can be the replacement of the chemical fertilizer and nutrient spray will also be the replacement against chemical spray, which ensures soil health (Phirke *et al.*, 2001).

Therefore, the organic food can be produced from soil containing vermicompost which might have export potential (Kumar *et al.*, 2012).

7. Implementation and Marketing Plan

The banana-waste-based business is possible to be started with minimum capital as raw martial cost is low and the machinery can be fabricated in Bangladesh using simple technologies. Therefore, the target should be only the extraction of fibre from banana tree if any one wants to start fibre based business (SAARC AgriNews, 2009). Entrepreneurs can either supply fibre in yarn textiles to make rope or supply yarn to textile after processing. Entrepreneurs can start from any segment like fibre based product manufacturing, paper and paper based products making, food processing, handicrafts or any kind of items those have discussed above. Entrepreneurs can collect fibre directly from banana cultivators by supplying essential machinery and providing proper training. Moreover, they can establish a well-equipped modern industry to manufacture all kinds of bio-products from raw materials sequentially. Actually, the implementation and marketing system depends on the essential capitals, business policy and enthusiasm of entrepreneurs. It is believed that this proposal not only be a simple business policy but also a guideline to community based development and rural mobilisation as well as to enhance wealth earning from waste to establish bio-economy concept in Bangladesh.

8. Conclusions

The products manufacture from banana fibre or other parts of banana tree will survive in market with a high competition. Addition of values to the banana bio-products will improve its quality and hence will enhance its acceptability. Addition of natural composites will reinforce the fibre for better strength and quality. The organic products are becoming increasingly popular worldwide. Therefore, government should take initiative in combination with scientists and technologists to prepare banana bio-products and reach the people in home and abroad, which in turn will contribute of food security. Banana fruits and its plants as a whole are a good source of bio-chemicals. Thus, bio-pharmaceutical industries can collect bio-chemicals from backyard industry and can save foreign remittance of Bangladesh. It seems that this information will be of immense help to the farmers, entrepreneurs, planners, scientists as well as Bangladesh government to take proper initiatives for the betterment of the nation.

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