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Review of value added products from waste cotton stalks

Nkosilathi Zinti Nkomo

Department of Fibre and Polymer Materials Engineering, National University of Science and Technology, P.O Box AC 939, Ascot, Bulawayo, Zimbabwe

Email: zintinkomo@gmail.com

ABSTRACT

Approximately two to three tonnes of cotton stalk are generated per hectare of cotton farmed, making available in Zimbabwe about a million tonnes of cotton stalks every season. Cotton is cultivated primarily for textile fibres, and little use is made of the cotton plant stalk which is considered an ecological burden. On average about two to three tonnes of cotton stalk are generated per hectare of land farmed. Cotton stalks are a waste by-product of cotton farming and a problem to dispose of as they tend to harbour parasites such as the pink bollworm. Burning of cotton stalks in the field is the preferred method as they would harbour several insects and pests which would be harmful to the future crop. The cotton mealybug has been described as a serious invasive polyphagous pest with a vast host range. The burning of the cotton stalks contributes to the emission of harmful greenhouse gases which pollute the environment. Approximately 0.85 million metric tonnes of CO_2 is produced per million metric tonnes of cotton stalk burnt. This study focuses on the value added products that can be obtained from the waste cotton stalks for farmers. Cotton stalks have potential end uses in manufacture of particle boards, preparation of pulp and paper, hard boards, corrugated boards & boxes, microcrystalline cellulose, cellulose derivatives, as a substrate for growing edible mushrooms, feed, organic fertilizers for soil amendment and have been shown to improve micro-organism activity and increase seedling growth. These different end uses can bring value addition to the cotton farming process increasing profit margins of farmers and the viability of farming cotton in Zimbabwe.

Key words: - boards, cotton stalks, paper, mushrooms

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1.0 Introduction

Cotton farming in Zimbabwe is of great importance to the economy of the country as it is the second largest export crop after tobacco (Esterhuizen, 2015). Cotton popularly known as “White Gold” is grown primarily for fibre and oil seed all over the world. In the 2014 farming season Zimbabwe produced 145000 tonnes of cotton (Nyamwanza Tonderai, 2014). On average about two to three tonnes of cotton stalk are generated per hectare of land farmed (R.M.Gurgar, 2007). Most of the cotton stalk produced is treated as waste, fuel or stock feed for cattle (R.M.Gurgar, 2007). The bulk of the cotton stalk is burnt in the fields after the harvest of the cotton crop although this is not desirable as it causes air pollution. Cotton growing continues to sustain livelihoods of farmers and is a major income generation sector for Zimbabwe (C.KAravina, 2012).

Cotton in Zimbabwe is predominantly farmed by small scale farmers situated in marginal rainfall areas on plots of average size of between one and two hectares (Anon., 2010). Fig 1.0 shows the major cotton farming areas in Zimbabwe. Cotton stalks kept in the fields after harvest are a breeding ground for the pink bollworm (pectinophora gossypiella), boll weevil, cotton mealybug (phenacoccus solenopsis) and other pests. The cotton stalks therefore are normally destroyed in the fields to prevent these pests from breeding. This presents a disposal problem to the cotton farmer. The farmers burn these cotton stalks in the field as the preferred disposal method. Burning of cotton stalks causes air pollution contributing to global warming. Approximately 0.85 million metric tonnes of CO_2 is produced per million metric tonnes of cotton stalk burnt (C.Sundaramoorthy, 2009). There is therefore a need to come up with more environmentally friendly methods of disposing of the cotton stalks. Cotton is cultivated primarily for textile fibres, and little use is made of the cotton plant stalk. The cultivation of cotton generates plant residues equivalent to three to five times the weight of the fibre produced (Reddy N, 2009). After harvesting the cotton bolls, the entire plant consisting of the stalk and leaves is a residue which remains in the field and the farmers usually destroy it by burning (Binod P, 2011). Burning of cotton stalks in the field is the preferred method as they would harbour several insects and pests which

would be harmful to the future crop (A.J.Shaikh, 2010).

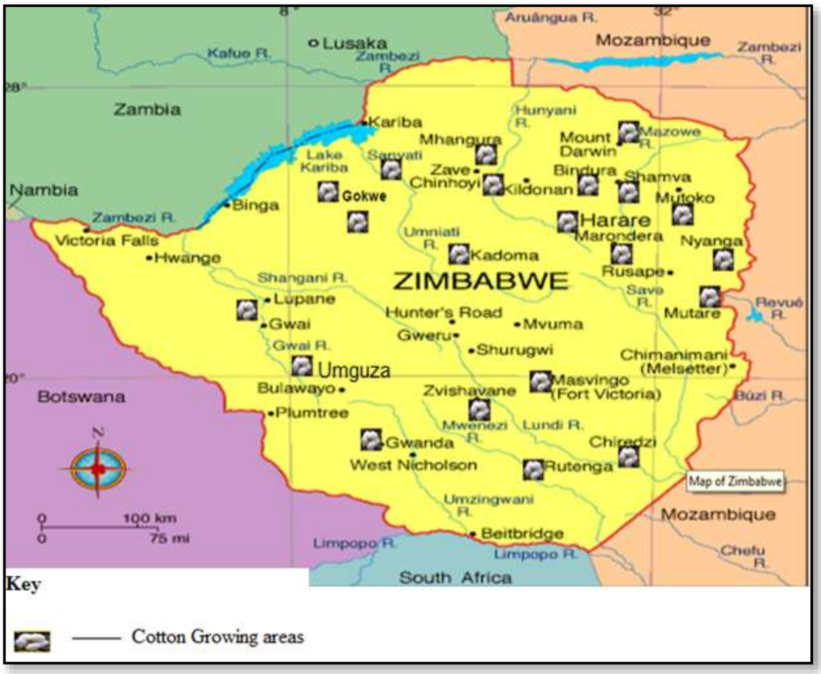

Figure Error! No text of specified style in document.**.1 Cotton growing areas in Zimbabwe (Anon., 1995)**

The cotton mealybug Phenacoccus solenopsis Tinsley (Hemiptera: Pseudococcidae) has been described as a serious invasive polyphagous pest with a vast host range (M.Vinobaba, 2014).

Cotton stalks contain about 46% of alpha cellulose and about 26% lignin and can be used as a raw material for preparation of various products (Jha, et al., 2008). Parlikar and Bhatawdekar (1987) reported its use for the preparation of microcrystalline cellulose (Parlikar & Bhatawdekar, 1987). The production of edible mushrooms on cotton stalks was reported by Balasubramanya (1981) (Balasubramanya, 1981). Shaikh and Sundaram (1998) developed a process for development of pulp and paper, and corrugated fibre board from cotton stalks (Shaikh & Sundaram, 1988). Cotton stalks have also been shown to be potential substrates for the growing of edible mushrooms.

2.0 Preparation of microcrystalline cellulose

Microcrystalline cellulose (MCC) has been widely used especially in food, cosmetics and medical industries as a water retainer, a suspension stabilizer, a flow characteristics controller in the systems used for final products, and as a reinforcing agent for final products such as medical tablets (Sakhawy & Hassan, 2006). MCC is normally obtained at an industrial scale through hydrolysis of wood and cotton stalk cellulose using dilute mineral acids. MCC has been prepared from coconut shells (Gaonkar & Kulkami, 1989), sugar cane bagasse (Padmadisastra & Gonda, 1989), ramie (Castro & Bueno, 1996), wheat and rice straws, jute, flax fibres and flax straw (Bochek, et al., 2003) and soya bean husk has been studied.

Wood pulp is a raw material in the paper industries. It is also used as a starting material for the preparation of valuable cellulose derivate, and demand for manufacturing paper, cellulose derivatives and viscose rayon has been increasing considerably in recent years. However these industries are facing a shortage of wood pulp due to depleting forest resources. In view of the growing shortage of wood pulp and considering its increasing demand in industries, there is a need for ascertaining the feasibility of replacing wood pulp by pulp extracted from agro waste material such as cotton stalks (Parakilar & Bhatawdekar, 1988). MCC has relatively low chemical reactivity combined with excellent compatibility at low pressures. MCC was rated the most useful filler for direct compression tableting. However a number of limitations to the use of MCC have been reported, the most prominent limitations being its low bulk density, high lubricant sensitivity, poor flow characteristics and the influence of moisture on the compression characteristics (Hassan & El-Sakhawy, 2005). A number of new grades of MCC have been introduced to reduce some of these problems.

3.0 Production of edible mushrooms

Mushrooms are the fleshy sporophores of fungi known to grow in nature on decaying cellulosic materials, dead wood, soil and manure pits. Mushroom, a macro fungus with a distinctive fruiting body, is a unique biota which assembles its food by secreting degrading enzymes. It decomposes the complex organic materials on which it grows (the substrate) to generate simpler compounds for its nutrition. Mushroom cultivation technology is environmentally friendly; the mushroom mycelia can produce a group of complex extracellular enzymes which can degrade and utilize the lignocellulosic wastes and thereby reducing pollution. Mushrooms can not only convert lignocellulosic waste materials into human food, but also can produce notable nutraceutical products, which have many health benefits (Girmay, et al., 2016). They provide people with an additional vegetable of high quality, and enrich the diet with high quality proteins, minerals and vitamins which can be of direct benefit to the human's immune systems and improve the quality of life. Mushrooms are also easily digestible and have no cholesterol content (Oei, 2003).

The majority of these fungi belong to the class Basidiomytina and a few to the class Ascomycotina. Edible fungi under the order Agaricales and the families Agaricaceae, polyporaceae and pluteaceae have been under commercial cultivation. The edible mushrooms are delicacy in food and form one of the choicest table dishes. They are rich in protein and an excellent source of vitamins and minerals. Most of the mushrooms have very low starch content and can form an ideal food for diabetic patients. Cultivation of oyster mushrooms on various crop residues is well known and it has been shown that Pleurotus spp can be successfully grown on rice straw, wheat straw, cotton stalks and other cellulosic materials (Bano & Srivastava, 1962). Lignocellulosic waste represents huge amounts of unutilized renewable resource.

Mushroom cultivation presents a worldwide expanded and economically important biotechnology industry that uses efficient solid state fermentation process of food protein recovery from lignocellulosic materials. The chemical properties of such lignocellulosic agricultural residues make them a substrate of enormous biotechnological value. They can be converted by solid state fermentation into various different value added products including mushrooms, animal feed enriched with microbial biomass, compost to be used as bio fertilizer or bio pesticide, enzymes, organic acids, ethanol, flavours, biologically active secondary metabolites and also for bioremediation of hazardous compounds, biological detoxification of agro-industrial residues and bio pulping (Pandey & Soccol, 2000).

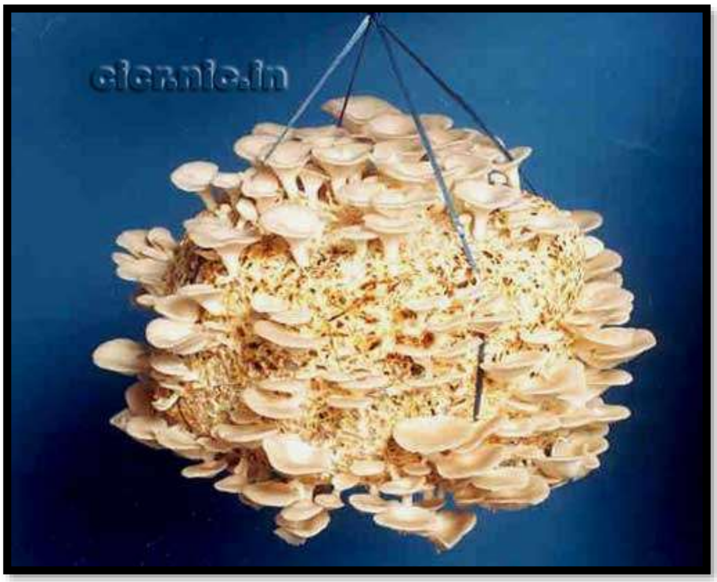

Fig 2.0 Mushrooms grown on cotton stalks (Balasubramanya, 2007)

Mushrooms yields up to 600g per kg and on supplementation with Bengal flour @ 3%, as much as 1000g of fleshy fruiting bodies can be harvested per kg of cotton stalks (CIRCOT, 2014). Fig 2.0 shows mushrooms grown on cotton stalk substrate.

The major obstacle to using cotton stalks as a mushroom substrate lies in its difficulty of preservation. This is attributed to the high water content and to the high level of soluble carbohydrates (2-4% as compared to 0.4-1.4% in wheat straw) (Silanikove & Levanon, 1986). The substrate gets rapidly overgrown by moulds resulting in spoilage and aerobic degradation (Hadar, et al., 1992).

The procedure for preparing cotton stalk substrate for mushroom production.

- Chipping of the cotton stalks
- Overnight soaking and boiling of the cotton stalks
- Cooling of the stalks after boiling
- Mushroom spawn is introduced into the cotton stalk polypropylene bags.
- Holes are punched into the bag and it is hanged on the wall.

Table 1.0 shows the high yield of mushroom from cotton stalks in comparison to other agro wastes that are generated such as wheat straw and rice straw.

Table 1.0 Yield of Pleurotus on different substrates (Hadar, et al., 1992)

Substrates	Mushroom species			
	P.sajor-caju	P.florida	P.flabellatus	P.ostreatus
Wheat straw	400	410	417	440
Rice straw	310	425	307	453
Pearl millet straw	365	440	362	513
Cotton stalks	480	453	450	600

*g/kg of the substrate

The mushrooms produced from cotton stalk substrate take approximately 25 days to mature and be ready for harvesting. The temperature must be maintained at 25-30 Degrees Celsius with a relative humidity of 55-80%. The bags must be kept in a dark room for the first twenty days then for the next ten days water must be sprinkled. Table 2.0 shows the stages of growth of the mushrooms on cotton stalk substrate.

Table 2.0 Stages of growth of mushrooms in cotton stalk substrate

Stage	Time (Days)
Spawn layer	1
Mycelium growth	15-20
Pin heads	20-24
Fruiting bodies	24
Harvesting stage	25-30

This is one of the low capital intensive projects that farmers can engage in to generate additional revenue from the waste cotton stalks.

4.0 Development of paper and pulp

Forests are shrinking day by day in respect of area as well as stockings, due to the growth of population, increasing demands for wood and various other biotic factors. But contrary to this, the demand for raw materials required for paper production is increasing. One of the ways of tackling this problem is the utilization of non-conventional raw materials like bagasse, mesta, wheat, rice and straws such as cotton stalks.

Pulps produced from cotton stalks could be an alternative raw material for pulp and paper industry (Akgul & Tozluoglu, 2009). Cotton stalk pulps can be used in the production of high quality printing and writing paper (Tutus, et al., 2010). Cotton stalks are suitable for producing mainly writing and printing papers or mixing with conventional wood pulps to produce paper fibres softwood for the production of high quality paper (Sadegh, et al., 2011).

of various uses (Ververis, et al., 2004). The cotton fibres can be mixed with other large Wooden boxes are commercially used for packaging and transport of goods such as fruits due to their light weight, foldability and resultant ease of storage. However the cost of the kraft paper manufactured from wood pulp can be a bit high. There is a possibility to switch over to more viable non-conventional and eco-friendly lingo-cellulosic raw materials such as cotton stalk pulp for the manufacture of the boxes.

The cotton stalks are put into a rotary digester and temperature raised. The cooked material can then be refined in a disc refiner in two passes and then thoroughly washed in mechanical washers and beaten in a valley beater to obtain pulp of desired freeness. Screening is then done to remove uncooked cotton stalk chips and fibre bundles (Shaikh & Varadarajan, 2003).

5.0 Development of Fibre boards

Fibres can be extracted from cotton stalks by water retting process and mechanical decortication. Retting is carried out for three weeks in drums and there after mechanical decortication can be carried out. The fibres are then removed and cleaned. Figure 3 shows the retting process of the cotton stalks .A composite material can then be developed using the extracted cotton stalk fibres and phenol formaldehyde resin to give fibreboards suitable for use in partition boards, table tops and furniture boards.

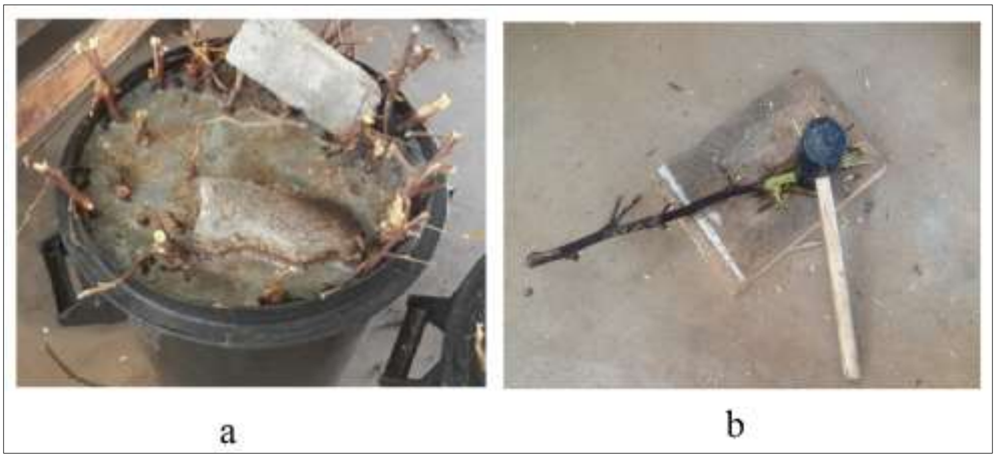

Fig 3.0 a) Water retting of cotton stalks b) mechanical decortication to extract fibres (Nkomo, et al., 2016).

6.0 Briquettes

Briquetting can be defined as the process of converting low bulk density biomass into high density and energy concentrated fuel briquettes. Process of translating biomass into solid fuel involves drying, cutting, gridding and pressing with or without the aid of a binder (Lavanya, et al., 2018). Cotton stalks and other agricultural residues have been shown to have potential use in the making of briquettes (Onaji & Siemons, 1993). Cotton stalks are cut into small sizes, dried and then pressed. The stalk briquettes can be used as a raw material when combined with coal or firewood to produce high quality fuel. It is also environmentally friendly as it does not produce as much smoke compared to charcoal.

According to studies by Lavanta et al, 2018 briquetting of the cotton stalk gave good quality briquettes as shown in table 3.0. The moisture content after briquetting was 4.44% which is less than 10% showing that this briquette is good for combustibility (Ilochi, et al., 2016).

Table 3.0 Characteristics of cotton stalk briquettes (Lavanya, et al., 2018)

Parameters	Units	Value
Before briquetting		
Moisture content	% (w.b)	13
Bulk density	Kgm^{-3}	187.66
After briquetting		
Compressed density	Kgm^{-3}	900.63
Relaxed density	$Kg\ m^{-3}$	886.61
Shatter resistance	%	93.66
Water absorption	%	32.96
Moisture content	% (w.b)	4.44
Ash content	%	3.89
Calorific value	Kcal kg-1	3197.47

The test results obtained show good shatter resistance which affects the handling and transportation of the briquettes. Cotton stalks are therefore a good source of biomaterial for the manufacture of briquettes.

7.0 Conclusion

Cotton stalks are an underutilised resources that is normally burnt in the fields contributing to the global warming crisis. Instead these cotton stalks can be collected and used in the paper and pulp industry for making good quality paper and cardboards. The cotton stalks can also be used for the growing of edible mushrooms adding value to the cotton farming process while providing an environmentally friendly manner of disposing of the cotton stalks. This is an avenue that can also provide affordable food source for the community. The cotton stalk fibre can also be extracted and fibreboards made from the fibres mixed with phenol formaldehyde resin. These boards can be used in partition boards, table tops and other furniture boards. The cotton stalks can also be used for the preparation of microcrystalline cellulose which is used in a number of industries such as the cosmetics and medicinal industry. The main problem with cotton stalks lies in its high transportation and storage cost due to their low bulk density. This could be solved through a densification process more research needs to be done in this area. Cotton stalks have been shown to make good briquettes which give good quality fuel.

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