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Review

The potential of *Aspergillus* species in transformation of agricultural products for sustainable production of textile and leather industries in Tanzania

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Manufacturing industries contribute about 8% of the gross domestic products (GDP) whereas leather and textile industries supply 18% employments of manufacturing industries in Tanzania. Manufacturing industries merely depend on agriculture for raw materials and other inputs. However, processing of leather and textiles requires a lot of inputs, many of them supplied from agricultural produce and some are imported from developed nations. In vast developing countries, including Tanzania, manufacturing industries are constrained by limited production technology and the allied costs than raw materials. The conventional processing of leather and textiles requires immense technological investment that is associated with high production cost. In Tanzania, inputs such as soaking, bating and tanning agents for tannery industries are expensive and sometimes not readily available due to importation costs. On the other hand, management of waste effluents from leather and textile processing is the major impediment for development of these industries. However, natural processing of covering materials by using fungal biotechnology is of great concern in Tanzania to avert the prevailing constrains. The application of fungal based biotechnology would reduce production cost and health consequences resulting from chemicals, particularly, chromium. The effects of toxic chemicals from leather and textile industries would be mitigated by employing non-viable *Aspergillus* biomass in the industrial processes. This would minimize production of the harmful wastes from the industries. As a result, leather and textile production would be achieved at low cost, without hazardous waste production, resulting to safer products for both human and the environment. This review evaluates current production of leather and textile industries and highlights the potentials of microbial biotechnology.

Key words: Biotechnology, *Aspergillus*, leather and textile, industrial effluents, agriculture.

INTRODUCTION

Agriculture remains the major supplier of food and income, to majority of rural communities though its production is less than demands (Korotayev and Zinkina, 2015; Shombe, 2008). In order to sustain life of both rural and urban inhabitants, agricultural produce must be processed and the value added will obtain new goods or increase the shelf life of existing ones (Shombe, 2008). Industrialization is the key for transforming agricultural

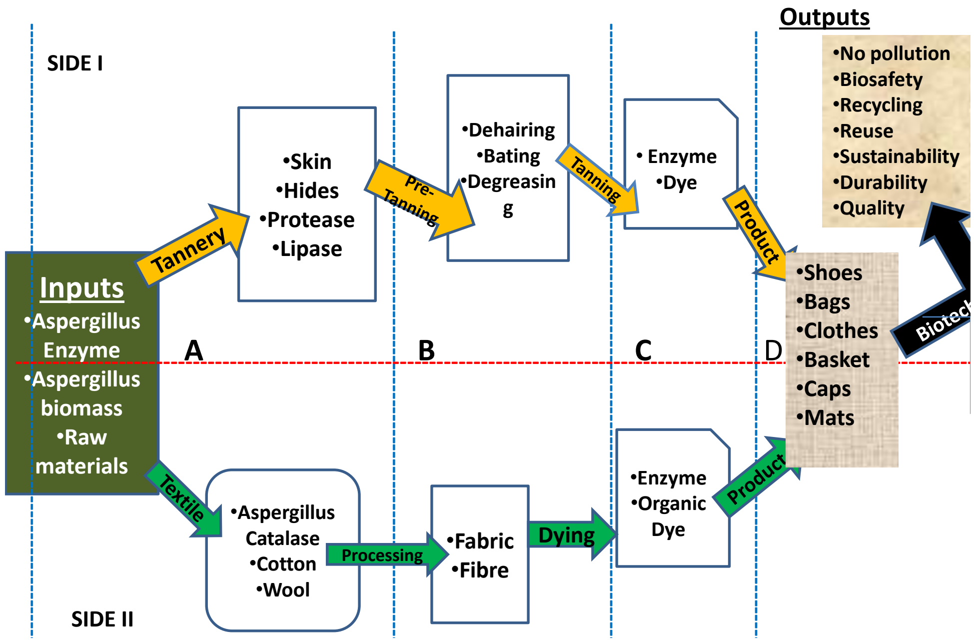

Figure 1. *Aspergillus* enzymic processing of textile and leather products.

produce by processing them into worthy products (Mwaigomole, 2014). Textile and leather are important ancient industries in Tanzania that contributed to, youth employment and exportation of goods in 1980's (Mwaigomole, 2014). Tanzania is the major producer of skin and hides which supply the industry with raw material and could export the excess.

However, the quality of hides and skin produced is squat due to poor handling and processing technologies (China and Ndaro, 2015). On the other hand, pest damage to agricultural produce weakens the quality of produce prior to processing (Kanui et al., 2016; Sertse and Wossene, (2007)), who reported the economic impact of ticks in tannery industries, in Ethiopia. Moreover, transformation of hides and skin into leather requires chemicals or enzymes as depicted in Figure 1, but chemicals are the current option in Tanzania. The cost of chemicals to the environment led to closure of some industries and is the main hindrance to production and exportation of goodsin Tanzania (ITC, 2016; China and Ndaro, 2015). Shutting down of these industries causes losses to owners and denies the national revenue. Other constrains challenging leather and textile industries are management of waste, that are claimed to be toxic to the environment. However, microbial industrial processing of skin hides and fibre into products is reported to be effective and safe.

Microbes are free living organisms found almost everywhere in the environment (Finlay, 2002). Their abundance ranges from marine, terrestrial, to fossils (Foissner, 2006). This is because they are well adapted to various environmental conditions (Finlay, 2002). Microbes are the ancient organisms that colonized the land and claimed to be the origin of life on earth (Falkowski et al., 2008; Mileikowsky et al., 2000). Nevertheless, microbes are mostly condemned for their negative impacts to human and other life forms, particularly disease-causing pathogens (Klich, 2007; Blumenthal, 2004).

On the other hand, whatever causes effect to human should be exploited on its potentials for industrial application (Zafar et al., 2007). For instance, the mycotoxins produced by *Aspergillus* spp. have economic importance in biotechnology industries (Cotty and Jaime-Garcia, 2007) despite the negative impacts caused to humans. It is clearly known that microbes play a greater role in sustaining lives of other creatures on earth (Schuster et al., 2002). They serve as sources of medicine for various infectious diseases, industrial processing enzymes, formation and balancing of nutrient composition in soil (Amaike and Keller, 2011).

Fungi play role in varied range of economic and development sectors including agriculture, textile and leathery industry (Cleveland et al., 2003). For instance,

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Aspergillus flavus is abundantly available in soil, agricultural produce and processed food (Perrone et al., 2007). Despite its availability in wide range of environment, it is complained by its ability to produce toxic metabolites such as Afflation that may lead to liver cancer (Klich, 2007). In Tanzania for instance, *A. flavus* has not been utilized for biotechnological industries rather complained and avoided for health concerns (Klich, 2007). However, the good side of *A. flavus* is its industrial records in other developed nations (Cardamone, 2002). *Aspergillus* species is essential for synthesis of proteolytic enzyme required by various industries (Chellapandi, 2010).

It is in this vein that *A. flavus* locally available in Tanzania could be used for industrial processing of skin, hides, wool and cotton for production of good leathery and cotton clothes. Moreover, effluent emitted by tanning and dying agents could safely be treated with *Aspergillus* biomass. Thus this article reviewed the potential of *Aspergillus* species with the main focus on *A .flavus* as an available option for safer leather and textile products for both human and the environment in Tanzania.

ASPERGILLUS IN INDUSTRIAL APPLICATION

The genus *Aspergillus* comprises of many economic important species with industrial applications (Oyeleke et al., 2010; Chellapandi, 2010). *Aspergillus* species are sources of vast industrial enzymes with varied application. Aspegillus species was reported to produce extracellular enzyme that is said to be effective in biocontrol of pest in cotton fields (Liu et al., 2001). *Aspergillus* species have been documented to produce many industrial benefits including tannery and textile processing products (Batra and Saxena, 2005). For the purpose of this review, only textile and leather industry is focused on. This is because tannery and textile processing are closelyrelated and they both produce covering materials.

Since the dressing materials need to be safe and comfortable to users, production of such products from natural processing should be safe. Conversely, textile and leather industries use toxic chemicals for tanning or dying raw fiber which cause environmental and health problems (Costa and Klein, 2006). However, most of *Aspergillus* species have multiples applications in these industries thus its application would avert such problem (Bayramoglu et al., 2006). For instance *A. flavus, Aspergillus niger* and *Aspergillus fumigutus* were reported to produce enzymes essential in tannery industry (Barthomeuf et al., 1994). Thanikaivelan et al. (2004) reported the potential of *Aspergillus tamarii* in tannery biotechnology whereas *Aspergillus terreus* was reported to produce tannery enzyme for processing leather (Tang et al., 2004).

More interestingly, *A. flavus* was revealed to produce proteolytic enzyme in processing of wool for textiles (Cardamone, 2002). On the other hand, Deepa et al. (2007) demonstrated the sorption role of *A. flavus* in textile effluents. Additionally, Sivakumar et al. (2014) reported the activity of *Aspergillus* in remediation of textile wastes for safe environment. Similarly, the most toxic Azo dyes from textile wastes were acted upon by *A. flavus* biomass (Akar et al., 2009; Ali et al., 2009; Singh and Singh, 2010). Various applications of *A. flavus* have been reported including pretreatment of industrial wastes before they are released to the environment (Esmaeili and Kalantari, 2012). Hence harnessing of local *Aspergillus*, species would decrease industrial production cost particularly in leather and textiles in Tanzania.

CULTIVATION, OPTIMIZATION AND ADAPTATION TO ENVIRONMENT

Aspergillus species are almost found in every environment on earth (Srividya et al., 2009; Ramirez-Camejo et al., 2012). They can easily adapt to the environment and simply be cultured to optimize them for commercial uses in industries (Guinea et al., 2006). Laxman et al. (2005), revealed how fungi populations could be optimized to increase production of enzymes that are essential for industrial manufacturing of leathery products. Many *Aspergillus* species have been optimized by using local materials for production of industrial enzymes (Devi et al., 2008).

There are several ways of developing and multiplying fungal colonies (Gervais and Polin, 2003). However, selection of culturing method usually depends on the desired products. The solid state fermentation has been pointed to be the best method of increasing production of alkaline enzymes from *Aspergillus* (Ellaiah et al., 2002; Muthulakshmi et al., 2010). This technique has many advantages over submerged method as it produces enough alkaline protease (Kumar and Takagi, 1999).

In addition to that, *Aspergillus* produces enzymes at low cost in which locally available materials from food remains can be used to produce, high amount of enzyme with reduced environmental pollution. This is because local materials like rice and wheat bran produce little waste on environment (Paranthaman et al., 2009). Another study done on *Aspergillus foetidus* revealed the ability of cheaply cultured fungus, in improving tannery processing (Purohit et al., 2006). Another study revealed that, *A. terreus* can be fermented on cheaply available materials and optimized to produce desired quality (Gao et al., 2008). Hence, use of locally available material such as wheat, rice and other cereals by cheap technology in optimization of *Aspergillus* would enhance activity at low costs.

APPLICATION IN LEATHER INDUSTRY

Leathery industry requires many inputs and involves a series of pre-tanning processes (Suresh et al., 2001). Prior to tanning, animal skins and hides are exposed to high enzymic processes or chemical treatments that are quite expensive (Thanikaivelan et al., 2005). A series of pre tanning processes such as dehairing and bating of raw skin and hides can be performed by using microbial enzymes to reduce costs (Macedo et al., 2005). Use of organic and microbial inputs, tanneries is not practiced in large scales though it is essential for biotechnological development.

However, use of chemicals such as chromium as tanning agents have a lot of negative implications and costly to the environment (Fahim et al., 2006). This chemical accumulates in the environment and may cause carcinogenic effect (Dayan and Paine, 2001) and has currently been implicated as one of the challenges in running leathery industry in developing and developed world (Fahim et al., 2006).On the other hand, application of enzyme in tannery processing is cheaper and has less or no toxic wastes (Aravindhan et al., 2007). Thus an option to use natural tanning agents and microbial enzyme for pre-tanning, offers more sustainable production of leather materials (Batra and Saxena, 2005). Various species of *Aspergillus* have been reported to produce enzymes for chemical reactions in industrial processing of raw skin and hides into leather (Thanikaivelan et al., 2004). *A. niger* was potentiated as good source of lipase for digestion of animal protein in leathering process (Paranthaman et al., 2009).

Additionally, it was reported that lipase from *A. niger* had recognizable action in digestion of animal fats from skin (Houde et al., 2004; Hasan et al., 2006). Production of protease by *A. flavus* has demonstrated the role of fungi in manufacturing industries (Kamini et al., 1999). Another research done by Malathi and Chakraborty (1991), reported the new alkaline protease produced by *A. flavus* useful in tannery industry.Kim (2007), revealed the ability of *A. flavus* in production of keratinase that is used in enzymic catalysis of keratin from feather. Moreover, Chellapandi (2010), revealed the production of tannery protease by *A. flavus* and *A. terreus*. Though many studies have been conducted on *Aspergillus* species, none has been documented as a potential of fungal biotechnology in textile and leather industries in Tanzania.

ASPERGILLUS SPECIES FOR TEXTILE PROCESSING

Textile industry is among the oldest industries that requires multiple inputs with processes (Chandra and Kumar, 2000). Wool and cotton undergoes various processes to obtain fabric for making clothes (Sousa et al., 2007). Microbial lacasses play a role in processing raw materials into fabric (Couto and Toca-Herrera, 2006) from *Aspergillus* species. However, this industry is constrained by management of dye wastes (Sawhney et al., 2008). Management of dye waste particularly the Azo dye is the main challenge (Mu et al., 2009). However, Araujo et al. (2009), revealed the ability of *A. niger* proteases in textile processing. More studies done on *Aspergillus* species revealed production of industrial catalytic enzymes for textile processing (Bhat, 2000; Parvinzadeh et al., 2008). Various classes of catalytic enzymes have been studied from *Aspergillus* so far (Kirk et al., 2002; Sukumaran et al., 2007). Catalytic enzyme such as amylase produced by Aspergilllus member was documented for its application in textiles (Alva et al., 2007).

On the other hand, enzymatic treatments by *A. flavus* have been evaluated and validated in textile wastes (Sawada et al., 2007). McMullan et al. (2001) reported the biodegradation activity of *Aspergillus* on textile dyes. Even the dead biomasses of *Aspergillus* species are useful in the elimination of accumulated industrial waste of heavy metals. *A. flavus* is also known as good biosorption of heavy metals that are harmful to human such as lead and copper (Akar and Tunali, 2006). The dead biomass of *A. niger* has high ability to absorb dye wastes from textiles (Khalaf, 2008). Other studies have also revealed its biosorption of complicated dye waste from textile industries especially the azo dye (Ranjusha et al., 2010). Thus, harnessing fungal products for industrial processing of textiles in developing countries including Tanzania would improve and promote sustainable production.

INDUSTRIAL WASTE MANAGEMENT

Leather processing uses chromium sulphate and other chemicals for tanning skin or hides (Srivastava et al., 2007). This chemical generates huge amount of wastes that are very toxic (Gotvajn et al., 2009) and are directed into public sewage system and finally, accumulate in soil and environment leading to health problems. Costa and Klein (2006) reported that chromium is one of very toxic chemicals that can cause carcinogenic problem to human. Removal of chromium from tannery waste by conventional methods is tedious, expensive and causes much hazardous impact to environment (Dayan and Paine, 2001).

However, *Aspergillus* species have good record in the management of industrial wastes and effluents (Joshi et al., 2011). *Aspergillus* species are capable of removing chromium from leathery wastes (Srivastava and Thakur, 2006). Sandana et al. (2006) revealed that *A. niger* absorbed chromium sulphate from tannery wastes. *A. niger* has been reported to absorb heavy metals such as copper and zinc from industry wastes (Prasenjit and Sumathi, 2005; Price et al., 2001). On the other hand, Srivastava et al. (2007) reported the role of *Aspergillus* in absorbing chromium sulphate from tannery effluent. Another study by Nasseri et al. (2002) revealed the potential of *Aspergillus oryzae* in absorbing chromium IV from tannery wastes. Furthermore, other studies revealed the ability of *Aspergillus candidus* in bioremediation of colored and toxic waste from tanneries (Murugan and Al-Sohaibani, 2010). Additionally, Prigione et al. (2009) reported the ability of *A. flavus* in the absorption of hazardous tannery waste.This finding revealed the potential of *A. flavus* in treatment of waste from industrial effluents.

POSSIBLE IMPLICATION IN LEATHERY INDUSTRY IN TANZANIA

Leather and textile are ancient industries in Tanzania and contribute to the national earnings. However, their production is currently decreasing due to a number of factors. One of the limiting factors is scarce and it limited inputs technologies including the use of microbial biotechnology that is cheaply available. *Aspergillus* species are the good source of industrial catalysts for processing of raw skin and hides. On the other hand, some *Aspergillus* members can produce tannery enzymes as well as absorbing tannery effluents, before they are released to soil and agricultural fields. Since vast majority of *Aspergillus* have demonstrated many industrial applications in both leather processing and removing of tannery wastes, optimization through mass culturing by using locally available resources would eliminate its scarcity. Most of *Aspergillus* species are naturally found in the environments and can also be cultured in large scale biotechnological laboratory to optimize the supply for industrial production. For instance, large amount of biomass of *Aspergillus* species was reported to absorb and eliminate large amount of chromium compound from tannery effluents (Sharma and Goyal, 2010).

Aspergillus is very abundant in Tanzania but not utilized for industrial production. The potential advantages of using native *Aspergillus* species, is low in production cost, technology and adaptability of products to local environments as postulated in Figure 1. Hence, screening and commercialization of *A. flavus* enzymes is of economic importance and would improve biotechnology development in Tanzania and across Africa continent.

Figure 1 represents the enzymatic processing of leather and textile products by using *A.flavus* products. The diagram consists of four main processing stages; A to D in both Side I and II, represent tannery and textile processing of raw materials, respectively. In Side I, skin and hides are the inputs (A) for processing leather which undergoes pre-tanning processes (B) by using alkaline proteases and lipase to obtain raw leather. Finishing is done by enzymic tanning and dying by *A. flavus* (C). Thereafter, desired product and other out puts are reached and viable and dead. *A. flavus* biomass absorbs wastes and release safe effluent to the soil in (D). On the other side II, processing of cotton and wool to get textile material is done in similar way using *A. flavus* but different raw materials. Cotton, wool and catalase (A) are the input for processing fibre and fabric (B).These materials are dyed under enzyme mild conditions (C), toxic waste is absorbed by *Aspergillus* dead mass, while products are produced in safety way (D).

CONCLUSION

Textile and leather industries remain the major producer of wear material in Tanzania. Hence, sustainable production requires efficient supply of quality skin, hides and fiber from well agricultural practices. Though, enzyme application processing of these industries is still underutilized in Tanzania.

Harnessing of *A. flavus* would improve industrial production and enhance safety of the products. This study evokes the attitude of harnessing natural and locally available resources such as *A.flavus* in development of biotechnology industries in Africa, to achieve desired products at low costs using locally available resources and technology.

Conflict of Interests

The authors have not declared any conflict of interests.

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