Proceedings of the International Conference on Agro-Biotechnology, Biosafety and Seed Systems in Developing Countries

www.scifode-foundation.org

Industrial Biotechnology Opportunities and Progress in Uganda

D. Wendiro

Uganda Industrial Research Institute, P.O Box 7086, Kampala, Uganda
Email: mukyalasande@yahoo.com; dwendiro@yahoo.com

ABSTRACT

Industrial biotechnology has potential to enliven and promote growth of the manufacturing industry of Uganda through creating intricate value chains with biomass as raw material for high value products. Uganda is endowed with biomass and many communities are engaged in manufacturing industry with prime focus in fermentative production of bio-chemicals including alcohols and fermented foods. Nonetheless, the scale and scope as well as the quality of products generated remain a challenge which effectively curtails growth of the industry. Consequently the contribution in terms of foreign exchange earnings from industrial biotechnology is extremely low. Key constraints which should be addressed with a view to enhance industrial biotechnology applications and services in production of biochemicals in Uganda include the following, among others: lack of systematic scientific promotion and failure to extend the technology frontier; lack of a long term strategy or policy; unplanned craft and job production design; focus on social welfare and survival instead of economic market behavior; lack of public awareness and acceptance of the potential of the technology; lack of necessary facilities to demonstrate commercial feasibility; and insufficient connectivity between the key players. Government should apply market pragmatism by systematic scientific promotion. Policy direction should complement markets in order to achieve a better long term outcome for the country's economy and society and provide necessary facilities to demonstrate commercial feasibility.

Keywords: *Biochemicals, economic markets, technology frontiers, value chains, Uganda*

Received: *4 December 2010,* ***Accepted:*** *28 December 2011*

Introduction

This article evaluates current and future contributions of industrial biotechnology and potential for progress in Uganda. Industrial biotechnology has a role in ensuring the steady growth of Uganda's manufacturing industry development. There are enormous opportunities, not just for the economy, but also to our environment and society. Industrial biotechnology has been practiced for a long time in a craft and job manufacturing system even to produce high quality products of world class. The technology identifies with the situation in developing countries where innovation is born out of need and there is no incremental innovation once something becomes useful (Dr. Kazungu D. Personal Communication, 2010 [1]). Moreover Ugandan manufacturers employ basic techniques where harnessing the environment is key to wealth creation. Industrial biotechnology is the use of biotechnology in industrial processes. Application of nature's tool set to the production of bio-based chemicals, materials and fuels.

Industrial biotechnology

Industrial biotechnology also known as "white biotechnology" is the use and application of biotechnology for the sustainable production of bio-chemicals, biomaterials and bio-fuels from renewable resources, using living cells and or their enzymes (Tang and Zhao, 2009). In the past, biological processes have been applied in industrial production such as making cheese, wine, beer, and with the advancement in

[1] Dr. David Kazungu commented in relation to indigenous innovations in a survey under IDRC funded project *"Traditional Science Technology and Innovations Systems in the Context of a Modern Incubator Research and Development Agency"* results are not yet published

scientific developments the list of products has expanded to include vaccine and hormones and biogum, among others. Enzymes which are derived from these products, organisms, are applied to catalyze a conversion in order to generate the desired products (Fig. 1).

Opportunities for industrial biotechnology

Whenever there is a market potential, there is an industrial opportunity. Uganda has a manufacturing industry with the prime focus in the second part of the value chain (Fig. 1), for production of biochemicals, biofuels and biomaterials. Typically the industry involves fermentative production of bio-chemicals including alcohols, and fermented foods. Value can be created in the social, environmental and economic sectors of industrial biotechnology which is yet to be uncovered.

Examples of emerging efforts to harness industrial biotechnology in Uganda include ongoing studies at the Uganda Industrial Research Institute (UIRI) to use Neurospora sitophila fungi to produce cassava detoxifying enzymes which precondition the cyanogenic glycosides for Xanthomonas campestris bacteria in the derivation of biogum a high value product. Social utility is created by providing safe cassava products of consistent quality on time, thus ensuring food security. Production of bitter cassava has both social and environment impacts since women prefer to grow them to allay household thieves (Wendiro and Otim-Anyoni, 2004[2]). This variety stays long in the soil hence is the only available source of food in periods of food shortage. Moreover bitter cassava varieties are resistant to pests and diseases and do well on marginal land (Aerni, P., 2004; NAARI, 2009).

In another study at UIRI, laccase enzymes (Novozymes 18043) derived from white rot fungi are being used in the removal of lignin from bark of Ficus species (Unpublished, ongoing study at UIRI). The use of enzymes has been shown to improve the fibre characteristics for textile manufacture. The bark is locally used to make bark cloth http://www.worldagroforestrycentre.org/sea/Products/AFDbases/AF/asp/SpeciesInfo.asp?SpID=866#Uses. Ficus species have for long been used as shade in banana and coffee plantations, its leaves are feed to small ruminants, it has medicinal value, and as wind breakers, and currently as timber for furniture since more traditional tree species are scarce (Zziwa, *et. al*., 2006; Brink, 2010). Innovative value addition to the fibre, which has so far been used for traditional purpose, would thus have resounding social, economic and environment impact, since harvesting the bark is usually non-destructive.

From the products generated, it is clear that industrial biotechnology has the potential for more sustainable livelihoods and competitive enterprises in terms of: low carbon revolution offering businesses the capability to develop and use less carbon intensive products and processes; reducing costs of production; and opening new, emerging and established markets. Market opportunities have been identified in many sectors; fibre based materials, bio-plastics and other biopolymers, surfactants, bio-solvents, bio-lubricants used in cosmetics, household and industrial detergents, paints and adhesives, ink and paper making, ethanol and other chemicals, pharmaceutical products, vaccines, enzymes, and cosmetics (Yang *et al*., 2002; Hsu and Lo, 2003; Rosalam and England, 2005; Salah *et al.*, 2010) .

Biomass energy is derived from trees and agricultural residues from the surrounding land cover such as farm lands, bush lands, woodlands, forests and grasslands. There is a rapid gain in transition towards renewable bio-based raw-materials. This market change will lead to further opportunities. The Lead Market Task Force on bio-based products predicted that the global market for bio-based products will grow to $ 250 billion by 2020 for a range of bio-based products including: fibre based materials (i.e. for construction sector or car industry); bio-plastics and other bio-polymers; surfactants; bio-solvents; bio-lubricants; ethanol and other chemicals and chemical building blocks; pharmaceutical products including vaccines, enzymes, and cosmetics (http://ec.europa.eu/enterprise/policies/innovation/files/lead-market-initiative/bio_based_products_taksforce_report_en.pdf).

Recently Government of Uganda is placing focus on science, technology and innovation (STI) and high value manufacturing. Industrial biotechnology resonates strongly in these areas considering that the prime focus of our traditional STI in the value chain is the fermentative production of bio-chemicals. Biomass is measured as the mass of organically bound carbon (C) that is present. The total live biomass on earth is about 560 billion tons of carbon. Forests contain about 80% of global terrestrial above-ground carbon stocks (biomass). Africa has the second largest block of rainforest in the world and is diverse in terms of the wide range of ecosystems. Uganda has a total area of about 241,551 km^2, out of which, farmland is the most extensive, followed by grasslands, woodlands, water bodies, bush land, tropical high forest (normally stocked), tropical high forest (degraded) and others in that order. The land area excluding water is about 20.5 million ha, out of which 4.9 million ha (about 24%) is covered by forests (plantations both hard and softwoods) tropical high forests (normal and degraded), and woodlands (Drichi, 2002).

In years to come Uganda's success will increasingly be defined by her competitive edge in industrial biotechnology and other knowledge-intensive industries. Industrial biotechnology has multiple impacts: it increases process efficiency and enables the use of renewable feedstock. It is a tool in the development of sustainable production processes. At global level, an environmental indicator that is relevant for all case studies on global scale is green house

---

[2] *Comment by a woman respondent in focus group discussion in Osukulu Subcounty Tororo District of Uganda, 2004 in a research on "Alternative technology approach to food security: A case of using enzymes in the detoxification of cassava." The use of enzymes was being tested for consumer acceptability. The woman commented in relation to cassava saying the husbands steal sweet cassava from house hold gardens and sell it to drink alcohol. With bitter cassava the situation is different because it requires processing, which the man cannot do stealthily.*

emissions. Biotechnology is among the key technologies that can help to address global warming, one of the most pressing environmental challenges; cleaner industrial biotechnology processes could thus enable countries to meet the international objectives in terms of carbon dioxide emissions, and pollution through anaerobic digestion, bioremediation or environment sequestration (Kumar, *et. al.*, 2011).

Industrial biotechnology makes industry more sustainable, it is expected that the benefits will be seen across a range of critical society-based arenas: job retention and creation, development of new technology platforms, and the reduction of society's dependence on valuable fossil resources, thereby conserving them for future generations. High-level education and research will be stimulated by providing high qualification employment and by developing R&D initiatives.

In Uganda, the niche for industrial biotechnology applications and services is apparent in aspects and sectors of food security and health intervention efforts for securing improvements in livelihoods. Examples of candidate projects for which industrial biotechnology can create value addition include the following:

- Local alcoholic beverages commonly called *tonto, malwa, mwenge bigere, muramba* etc contributes a percent to the "informal sector" economy. Some Ugandans are educated by proceeds from that industry, and some jobs are created in this way such as maize growing, and sieving (Mwesigye and Okurut, 1995; Namugumya and Muyanja, 2009)
- Processing and use of fermented soybean popularly known as tempeh to fight persistent diarrhea would have economic, health and food security benefits. It has been reported that 50% of diarrhea related deaths in developing countries are associated with persistent diarrhea disease. Isolation of enteropathogenic *Escherichia coli* in stool samples was associated with 28.4% of conversion to persistent diarrhea (de Andrade, *et. al.*, 2011), Invitro extracts of tempeh were found to inhibit adhesion of enterotoxigenic *Escherichia Coli* to intestinal brush boarder membrane of piglets (Kiers, *et. al.*, 2007).
- The alcohol powered bicycle launched by Honorable Jimmy Akena of Lira Municipality in Lira Town (Kiwuuwa, 2008) could contribute to improved health access; and poverty reduction by opening new markets for an already existing product – waragi, which is currently sold cheaply to local consumers whose health is also at risk due to consuming it
- Low carbon revolution offering businesses the capability to develop and use less carbon intensive products and processes (van der Zwaan, *et. al*., 2002, Chen, *et. al.*, 2011)
- Specialty cosmetic products that are over 60% organic and high value using organic stabilizers, and herbal extracts targeting lucrative niche markets of upscale consumers who prefer organic products
- Unprocessed essential oils extracted from natural herbs are being exported and or sold locally including thyme, white eucalyptus, citronella, ginger, coriander, ocimum, and tagette, to mention but a few (Wren, 2003), which have great opportunity in high value market sectors such as pharmaceuticals (Chen, *et. al*., 2011) and cosmetics (Prabuseenivasan, *et. al.*, 2006)

Based on the value chain approach, industrial biotechnology has a lot to offer (Figs. 1 - 3) in terms of value addition to raw materials, job creation, innovation and saving resources for future use. The pace of technology development is one of the most important factors that determine the rate of market growth. There is limited systematic scientific promotion and extension of technology frontier, which has resulted into slow growth of the manufacturing industry.

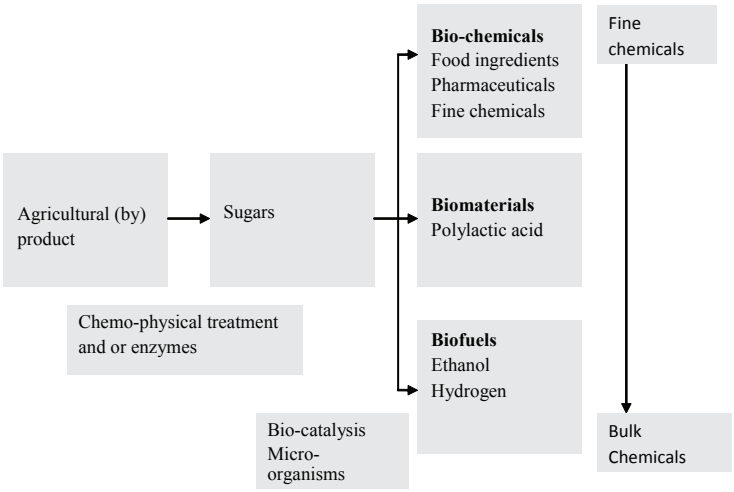

Figure 1: Industrial Biotechnology Value Chain

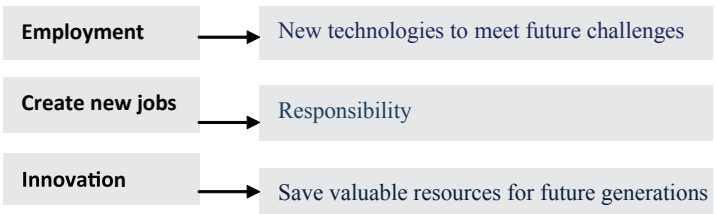

Figure 2: Impact of industrial biotechnology on society

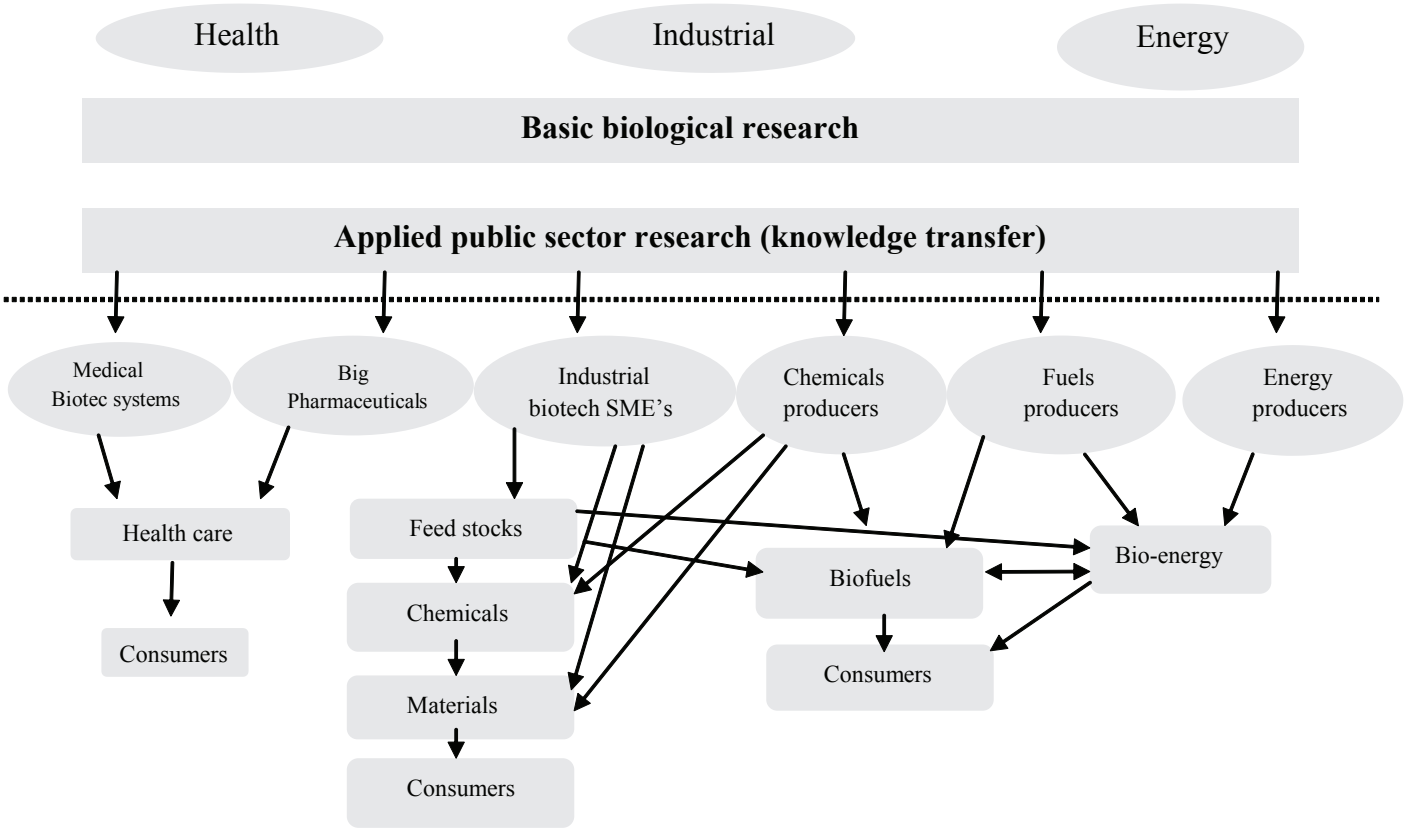

Figure 3: Impact of industrial biotechnology on society

Key issues which should be addressed to catalyze the deployment of industrial biotechnology include the following, among others: establishment of systematic scientific promotion; adoption of a long term strategy or policies; crafting and adoption of job design; focus on social welfare and survival instead of economic market behavior; enhancement of public awareness and acceptance of the potential of industrial biotechnology applications and services; investments to establish facilities to demonstrate commercial feasibility; and enhanced coordination among the key players in industry.

Government should apply market pragmatism to policy direction to complement markets and achieve a better long term outcome for the economy and society. The criteria for selection should include indigenous STIs that could generate viable products for niche markets; opportunities provided by trade and availability of natural resources; prospects for deepening value chains (opening way for other uses); environment impact, social cultural factors such as gender issues and geographical proximity to the central marketing district; available technological capability; and strategies to exploit new opportunities, for high value products like biogum processing, biofuels and textiles from bark of Ficus species. More attention should be paid to factors controlling science, technology and innovation (STI), diffusion and commerce.

There is need for specific scientific promotion, advancement of technology frontier and application of a business support regimen representing a precise flexible pattern to complement efforts of indigenous STI to reach a threshold level for development; develop S&T capabilities that are critical in creatively exploiting knowledge for economic, social and political aims (like a wide variety of design and engineering activities) (Wamae, 2009). This would aid local firms to acquire state-of-the-art technologies that would enhance their competitiveness in global trade. Centres for indigenous science, technology and innovation systems should be established to identify viable innovations, study, develop and package them for the market as typically African products to fast track industrial development, and courses in innovation should be included in curriculum at all education levels.

The next generation of biotechnological advancements will continue to require interdisciplinary communication among engineers, biologists, and physical scientists. Likewise, in all aspects of bioengineering, biology helps provide the framework for understanding which questions and problems are important, while the engineering is critical to developing effective solutions. Hence the cross-disciplinary exposure gained by engineers and biologists working in interdisciplinary teams, will have an impact beyond the development of immediate applications.

References

Aerni, P., 2004. 10 Years of Cassava Research at ETH Zurich: A Critical Assessment. *Swiss Centre for International Agriculture (ZIL)*. Available at: http://www.northsouth.ethz.ch/research_collaboration/agricultural_research/livestock_concept/livestock_concept/ZILsCassavaImpactStudy.pdf. Accessed 14/July/2011

Brink, M., 2010. *Ficus bussei* Warb. ex Mildbr. & Burret. In: Brink, M. & Achigan-Dako, E.G. (Editors). Prota 16: Fibres/Plantes à fibres. [CD-Rom]. PROTA, Wageningen, Netherlands. Available at: http://database.prota.org/PROTAhtml/Ficus%20bussei_En.htm. Accessed: 19/July/2011

Chen, H., Akinkurolere, R. O., Zhang, H., 2011. Fumigant activity of plant essential oils from *Armoracia rusticana* (L.) on *Plodia interpunctella* (Lepidoptera: Pyralidae) and Sitophilus *zeamais* (Coleoptera: Curculionidae). *African Journal of Biotechnology.* 10 (7), 1200-1205. Available at: http://www.academicjournals.org/AJB/full%20text/2011/14feb/Chen%20et%20al.htm. Accessed: 20/July/2011

de Andrade, J. A. B., Fagundes-Neto, U., 2011. Persistent diarrhea: Still an important challenge for the Pediatrician. *Jornal de Pediatria*, 87, 3, 199-205. Available at: http://www.scielo.br/pdf/jped/v87n3/en_a04v87n03.pdf. Accessed: 20/July/2011

Dr. David Kazungu comment in relation to indigenous innovations in a survey under the International Development Research Council (IDRC) funded project *"Traditional Science Technology and Innovations Systems in the Context of a Modern Incubator Research and Development Agency"* being implemented by Uganda Industrial Research Institute; Un-published

Drichi, P., 2002. National Biomass Study. Technical Report. Forest Department, Ministry of Water Lands and Environment, Kampala, Uganda.

Hsu, C., Lo, Y. M., 2003. Characterization of xanthan gum biosynthesis in a centrifugal Packed-bed reactor using metabolic flux analysis. *Process Biochemistry*, 38, 1617-1625

Kiers, J. L., Nout, M. J. R., Rombouts, F. M., Nabuurs, M. J. A., van der Meulen, J., 2007. A high molecular weight soluble fraction of tempeh protects against fluid losses in Escherichia coli-infected piglet small intestine. British Journal of Nutrition, 98, 320-325. Available at: http://journals.cambridge.org/download.php?file=%2FBJN%2FBJN98_02%2FS0007114507721463a.pdf&code=a8ff9811dbaa5cd07005a5003ed21b36. Accessed: 19/July/2011

Kiwuuwa, P., 2008. Waragi bicycle to work as ambulance in rural areas. The New Vision of Wednesday 13th February 2008. Available at: http://www.newvision.co.ug/D/8/26/611273. Accessed: 08/February/2010

Kumar, A., Beisht, B. S., Joshi, V. D., Dhewa, T., 2011. Review on bioremediation of polluted environment: A management tool. *International Journal of Environmental Sciences, 1, 6, 1079-1093.* Available at: http://ipublishing.co.in/jesvol1no12010/EIJES2061.pdf. Accessed: 20/July/2011

Lead Market Task Force of the European Commission {COM (2007) 860 final}; Report on Bio-based Products, Composed in preparation of the Communication "A Lead Market Initiative for Europe" Accelerating the Development of the Market for Bio-based Products in Europe. Available from: http://ec.europa.eu/enterprise/policies/innovation/files/lead-market-initiative/bio_based_products_taksforce_report_en.pdf. Accessed: 08/February/2010

Mwesigye, P. K., Okurut, T. O., 1995. A survey of the production and consumption of traditional alcoholic beverages in Uganda. Process Biochemistry, 30, 6, 497-501. Available at: http://www.sciencedirect.com/science/article/pii/0032959294000336. Accessed: 19/July/2011

Namugumya, B. S., Muyanja, C. M. B. K., 2009. Traditional processing, microbiological, physiochemical, and sensory characteristics of kwete, a Ugandan fermented maize based beverage. African Journal of Food, Agriculture, Nutrition, and Development, 9, 4, 1046. Available at: http://findarticles.com/p/articles/mi_7400/is_4_9/ai_n35541748/: Accessed: 19/July/2011

NAARI, 2009. (Namulonge Agricultural and Animal Production Research Institute). A country case study towards a global cassava development strategy. Available at: ftp://ftp.fao.org/docrep/fao/009/A0154E/A0154E04.pdf. Accessed: 19/July/2011

Novozymes 18043 Generally Recognized as Safe notification GRAS Notice 000122. Available at: http://www.accessdata.fda.gov/scripts/fcn/gras_notices/grn000122.pdf. Accessed: 14/July/2011

Prabuseenivasan, S., Jayakumar, M., Ignacimuthu, S., 2006. *Invitro* antibacterial activity of some plant essential oils. BMC *Complementary and Alternative Medicine*, 6, 39, 1-8. Available at: http://www.biomedcentral.com/1472-6882/6/39. Accessed: 20/July/2011

Rosalam, S., England, R., 2005. Review of xanthan gum production from unmodified starches by *Xanthomonas camprestris* sp. Available from: http://www.aseanbiotechnology.info/Abstract/21019023.pdf Accessed: 08/February/2010

Salah, R. B., Chaari, K., Besbes, S., Ktari, N., Blecker, C., Deroanne, C., Attia, H., 2010. Optimization of xanthan gum production by palm date (phoenix dactylifera L.) juice by-products using response surface methodology. J*ournal of Food Chemistry,* 121, 627-733

Tang, W., Zhao, H., 2009. Industrial biotechnology: Tools and applications. Biotechnology Journal, 4, 1725-1739: Available at http://chbe.illinois.edu/~zhaogrp/images/HZ84%20Industrial%20biotechnology.pdf: Accessed: 08/February/ 2010

van der Zwaan, B. C. C, Gerlagh, R., Kloassen, G., Schrattenholzer, L., 2002. Endogenous technical change in climate change modeling. *Energy Economics.* 24, 1-19. Available at: http://lyrawww.uvt.nl/~rgerlagh/papers/energyecon_24_1.pdf. Accessed: 20/July/2011

Wamae, W., 2009. Enhancing the role of knowledge and innovation for development. *International Journal of Technology Management and Sustainable Development*, 8 (3), 199-220

Wendiro, D., Otim-Anyoni, G., 2004. "Alternative technology approach to food security: A case of using enzymes in

the detoxification of cassava" un-published research sponsored by the Network of Ugandan Researchers and Research Users (NURRU)

World Forestry Centre, Agro Forestry Tree Database. A tree species reference and selection guide. Available at: http://www.worldagroforestrycentre.org/sea/Products/AFDbases/AF/asp/SpeciesInfo.asp?SpID=866#Uses. Accessed: 19/July/2011

Wren, S., 2003. Uganda herbs, spices and essential and fixed cosmetic oils. Summary report. Available at: http://www.grolink.se/epopa/publications/Summary_Report_Herbs_Spices_EssOils.pdf. Accessed: 20/July/2011

Yang, T.C., Wu, G. H., Tseng, Y. H., 2002. Isolation of a *Xanthomonas campestris* strain with elevated β-galactosidase activity for direct use of lactose in xanthan gum production. *Letters in Applied Microbiology*, 35, 375-279

Zziwa, A., Bukenya, M., Sseremba, O. E., Kyeyune, R. K., 2006. Non-traditional tree species used in the furniture industry in Masaka District, Central Uganda. *Uganda Journal of Agricultural Sciences*, 12 (1), 57-66. Available at: http://www.naro.go.ug/UJAS/Papers/vol.12,no1-7.pdf. Accessed: 19/ July/ 2011