

gh /
HD 8690
dzo



**KWAME NKUMAH UNIVERSITY OF
SCIENCE AND TECHNOLOGY, KUMASI**

DEPARTMENT OF BIOCHEMISTRY

PROFESSORIAL INAUGURAL LECTURE

PROF. (MRS.) VICTORIA PEARL DZOGBEFIA

Bsc Kumasi, PhD Oregon State University, USA

**"THE SILENT AND INVISIBLE
FACTORY WORKERS:
CREATORS OF WEALTH FOR
'SMART' NATIONS"**

OCTOBER 30, 2009

October

GHANA COLLECTION
KNUST LIBRARY

gh / HD 8690

d30

DZOGBEFIA, V. P.

Silent and invisible
factory workers:
creators of wealth for
'Smart' nations.

0200000106727

KNUST Main Library



KWAME NKRUMAH UNIVERSITY OF SCIENCE
AND TECHNOLOGY, KUMASI

GHANA COLLECTION
KNUST LIBRARY

PROFESSORIAL
INAUGURAL LECTURE

PROF. (MRS.) V.P. DZOGBEFIA
BSc Kumasi, PhD Oregon State University, USA
Professor of Biochemistry
Department of Biochemistry, KNUST

"THE SILENT AND INVISIBLE FACTORY WORKERS:
CREATORS OF WEALTH FOR
'SMART' NATIONS"

OCTOBER 30, 2009

LIBRARY
KWAME NKRUMAH UNIVERSITY OF
SCIENCE AND TECHNOLOGY
KUMASI-GHANA



PROFESSOR (MRS.) VICTORIA PEARL DZAGBRAFIA

BSC. KUMASI, PHD OREGON STATE UNIVERSITY, USA

DEPARTMENT OF BIOCHEMISTRY, KNUST

LIBRARY
KUMASI UNIVERSITY OF
SCIENCE AND TECHNOLOGY
KUMASI-GHANA

PROFILE OF PROFESSOR (MRS.) VICTORIA PEARL DZOGBEFIA

Prof. (Mrs.) Victoria Pearl Dzogbefia was born on 17th April, 1949 at Have in the Volta Region to Mr. Emmanuel Kwaku Agbloyor and Madam Gladys Amosi Abiti, both of blessed memory. She started her primary education at an advanced age of eight years in 1957 at the Have E.P. Primary and Middle Schools from where she proceeded to Mawuli School, Ho for both the Ordinary and Advanced Level Certificates from 1963–1969; having been promoted three times up to this period.

In October 1969, Prof. Dzogbefia gained admission into the Kwame Nkrumah University of Science and Technology to pursue a four-year degree programme in biochemistry which she completed in 1973 with a First Class Honours. Soon after graduation, she got a vacation appointment at the Building and Road Research Institute of CSIR as a Research Assistant. From October 1973 to August 1974, she served her National Service period as a Teaching Assistant in the Department of Biochemistry.

Prof. Dzogbefia won the African Graduates Fellowship (AFGRAD) from the African American Institute (AAI) to pursue her PhD in Biochemistry at the Oregon State University, USA from September 1974 – June 1979. During this period, she worked briefly as a Research Assistant in the Department of Biochemistry and Biophysics. After completing her PhD in 1979, she joined the Department of Biochemistry, Kwame Nkrumah University of Science and Technology as a lecturer in December 1979. She was promoted to Senior lecturer in 1986, Associate Professor in 1997 and Full Professor in 2007. She also holds a Certificate in Industrial Biotechnology and had training in Mushroom Biotechnology, both from Germany in 1992 and 1994 respectively.

Prof. Dzogbefia was Head, Dept. of Biochemistry from 1998–2003; Vice-Dean in the then Faculty of Science (now College of Science) from 1999–2003 and became the Foundation Dean of the Faculty of Biosciences from 2005–2008 when the Collegiate system was introduced. She served as the Ag. Vice-Dean, School of Graduate Studies (May–Dec. 2004).

Prof. Dzogbefia won several international travel awards to attend conferences and training workshops in USA, Germany, Italy, South Africa, Kenya, and Cameroun among others. From 1990–1991, Prof. Dzogbefia was a visiting scholar to the cocoa molecular biology laboratory in the Pennsylvania State University, USA. Between October and December 1994, she was also a visiting scholar to the mushroom research laboratory of the Institute of Soil Biology – Federal Agricultural Research Centre in Braunschweig, Germany where she undertook training in mushroom biotechnology.

At the international level, Prof. Dzogbefia currently serves as a reviewer for the following international journals:

Journal of Food Biochemistry (USA),

African Journal of Biochemistry;

African Journal of Agricultural Research;

African Journal of Food Science.

She is currently a member of the International Electronic Working Group on Guidelines for detection of specific DNA sequences in foods derived from modern biotechnology. She was a member of the Ghana delegation to the international workshop on "Tailor-Made Biotechnology for Endogenous Development" (TMBT) in Kisumu, Kenya in 2003.

At the National level, Prof. Dzogbefia is a member of the Sub-committee of the National Codex Committee on Foods derived from use of modern biotechnology; Member, Sub-committee of Vice-Chancellors Ghana, on

Memorandum of Understanding with Ministry of Public Sector Reforms; Resource Person for the Annual Meeting between Cocoa Research Institute of Ghana Management Board and Research Staff for review of Progress Reports and Work Plans.

She has served as External Examiner for University of Ghana, University of Cape Coast and University for Development Studies, Tamale. She also served as External Assessor for several staff promotions in the University of Ghana Legon; Council for Scientific and Industrial Research; Ghana Atomic Energy Commission and recently, The Methodist University College, Ghana.

In the Kwame Nkrumah University of Science and Technology, she has served on several committees including the Academic Board, Search Committee for the appointment of Provosts of College of Health Sciences as well as College of Agriculture and Natural Resources. In the then Faculty of Science, she was Chairperson for the Examination Malpractices Committee for several years in addition to a number of other Committees of the university that she chaired.

Prof. Dzogbefia was the 1999 Honoree of the "International Who's Who of Professional and Business Women", 6th Edition, from the American Biographical Society.

Prof. Dzogbefia currently has 62 publications to her credit of which 26 are in peer reviewed journals while the rest are conference publications, abstracts and reports.

Research interests: Biotechnology – Production of enzymes from microbial sources and their use in food processing; conversion of agricultural wastes into mushrooms and other value added products using mushrooms as biocatalysts.

Professor Dzogbefia is married to Mr. Mawuena Dzogbefia and they have three lovely children – Kafui (Building Technology Graduate), Mawutor (Medical Doctor) and Woedem (Postgraduate Architecture Student).

Professor Dzogbefia is a Christian and an active member of the Global Evangelical Church – Ayigya branch, where she is a devout chorister. She has served as Synod Committee Member and Kumasi Presbytery Executive Member of the Church for Eight years in both cases. She is currently the Board Chairman of the Global Impact Foundation, an NGO of the Church.

Salutation:

Mr. Chairman,

Pro Vice Chancellor

Registrar

Provosts

Deans and Directors

Heads of Department

Colleague Professors and Senior Members

The Clergy hereby present

Family Members

Junior Members *in statu pupillari*

Members of the Press

Distinguished Invited Guests and Friends

Ladies and Gentlemen,

GRANA COLLECTION
KNUST LIBRARY

I would like to start this lecture with the words of the Apostle Paul in I Cor. 1: 26 – 29 and I quote:

"Brothers, think of what you were when you were called. Not many of you were wise by human standards; not many were influential; not many were of noble birth. But God chose the foolish things of the world and the despised things and the things that are not to nullify the things that are, so that no-one may boast before him" unquote.

This scripture, Mr. Chairman, aptly describes my feelings today because of my background. At the age of close to eight years when all my younger siblings were in school, I was running about in the cocoa plantations in Togo. Least did it ever cross my mind that I would one day have the opportunity to go to school up to the university, become a university lecturer and rise to the enviable position of a full Professor! Indeed *"This is the doing of the Almighty God and it is marvelous in my eyes"*. It is, therefore, with great humility and gratitude to God that I stand before you this afternoon to deliver a Professorial Inaugural Lecture, which incidentally also happens to be the first Inaugural Lecture to be given by a female in the history of KNUST.

LIBRARY

KWAME N. UDOAH UNIVERSITY OF
SCIENCE AND TECHNOLOGY
KUMASI-GRANA

Acknowledgements

Mr. Chairman, several people have contributed to what I am today, and I wish to acknowledge some, at least in this lecture.

- My dear parents, Mr. Emmanuel Kwaku Agbloyor and Madam Gladys Amosi Abiti of blessed memory, who at a period when higher education of the girl child was the exception rather than the norm, sacrificed their meager resources as village carpenter and seamstress respectively to send me to school up to university level
- My Brother, Justice E.B.K. Agbloyor who coached me in English for the Common Entrance Examination and who was prepared at one point in our education, to interrupt his if necessary, so I could go on when things became very difficult for our parents
- My cousins Mr. O.K. Atubra, Drs. C.D. Anyomi and Charles Asembri for their keen interest in my academic progress from Middle School up to the university
- The then Cocoa Marketing Board (CMB) for offering me full scholarship which came with my admission letter to Mawuli School, without which there would have been no way I could have gone to secondary school
- Prof. Wilbert Gamble, my Ph. D supervisor who trained my hands and mind for good scientific research
- Current Pro Vice -Chancellor, Prof. W.O. Ellis, though was once my student at undergraduate level has been of immense challenge and encouragement to me over the years
- Prof. J.H Oldham, who was my mentor right from my undergraduate years up to this very day
- Colleague lecturers and Staff of Biochemistry Department for their friendship, support and encouragement
- Profs. K. Singh and R.K. Nkum former Deans of Faculty of Physical Sciences for their encouragement. They took time to go through the application document for me before its submission
- The people of Have, my hometown, who, demonstrated to its fullest, what I term "home support" for girl child education, since I was the first girl from Have to have had a university education

- The most important person in my life, my husband, Mawuena who helped me with A-Level Biology *though with no strings attached at the time*. Again while working for my PhD, he was virtually the baby sitter for our daughter most of the time that I was in the lab at night. My husband also encouraged me to go into the Ph. D programme when I was reluctant because I was then three months pregnant with our first child
- Finally, my children and all the numerous people that stayed with us for creating a peaceful environment at home that enabled me pursue my professional career goals. I am grateful to you all.

1.0 INTRODUCTION

Life, as we know it, Mr. Chairman, will not be possible without what I call the "***silent and invisible factory workers***". These workers help carry out nearly all chemical reactions in living systems. They increase the rates of reactions that would naturally occur, but cannot initiate a reaction that would not ordinarily occur. Thus it will be an understatement that "without these factory workers, all life processes will cease"

The following scenario will illustrate one simple aspect of the power of these "silent and invisible factory workers":

"In the absence of these workers, Mr. Chairman, the starch in your last evening's "fufu" or "banku" would break down to simple sugars for your energy, but the process would take hundreds, if not thousands of years to complete. In presence of these "factory workers" found in your digestive system however, the job would have been completed before you woke up from bed this morning" (Boustead and Walker, 1991).

These 'silent and invisible factory workers', Mr. Chairman, are called 'enzymes' in the language of biochemistry. In this lecture, I intend to give you some insight into the nature of these factory workers, what they do, why they are silent and invisible and their role in wealth creation. I will then use the remaining half of the lecture period to update this august audience on what I have been doing with these factory workers over the last 30 years as an enzymologist and a biotechnologist. The lecture will be concluded with some reflections and recommendations.

1.1 Some facts on the "silent and invisible factory workers"

Enzymes perform many functions in all living systems to sustain life. They are the manual workers that build our bodies from the nutrients consumed in our foods to make life possible. Enzymes perform their functions as catalysts which are not used up in the process, but are able to transform the substances required by the body and then use or eliminate the transformed substances as and when it may be needed by the body.

In Jeremiah 1: 10, the Lord instructed Jeremiah thus, and I quote: *"See, today I appoint you over nations and kingdoms to uproot, and tear down, to destroy and overthrow, to build and to plant"* (unquote). (NIV)

In a similar manner Mr. Chairman, *"Enzymes work as tireless, highly skilled workers on a factory conveyor belt, dismantling, controlling, protecting, destroying, eliminating, re-assembling, or performing whatever task is needed by the organism, including man, in order to survive day and night. After completing their missions and life spans, enzymes themselves age as our bodies do and need to be replaced. In good health however, there is always a new supply of enzymes, able and ready to keep on working till"*? <http://www.blurtit.com/q783336.html>

Mr. Chairman, in the kitchen, when a woman suddenly rushes out into a backyard garden, plucks an unripe pawpaw, peels it, and adds the sliced green fruits to some meat on the stove and allows it to boil, what she is doing in essence is asking a "silent and invisible factory worker" to soften the meat for her. Unripe pawpaw, especially the latex, is a rich source of an enzyme called papain, which breaks down proteins. Thus the tough muscle protein of beef can easily be made tender with the help of papain from pawpaw within a short period of time. This is the principle behind the commercial production of all meat tenderizers. However, nobody physically sees or hears enzymes when they are at work. *Is there any doubt therefore that they are indeed the 'silent and invisible factory workers'?*

2.0 DISCOVERY OF ENZYMES (ADAPTED FROM NSIAH, 2005)

Science, as we know it, is the process of a series of observations followed by tests from which conclusions are drawn. Discovery of enzymes was similarly made. In 1783, Spallanzani and Reaumur studying the dissolving action of gastric juice from birds on a piece of meat suggested that the digestion of proteins in the stomach was not a mechanical process. The compound pepsin was later on found in the gastric juice and shown to be involved in the digestion of meat proteins. Berzelius also proposed in 1837 that fermentation was a catalytic process when he showed the breakdown of starch by a malt extract and proposed the theory of enzyme catalysis. Peroxidase and polyphenol oxidases were discovered in 1855. In presence of hydrogen peroxide, peroxidase caused a gum solution to change from brown to blue, whereas the polyphenol oxidases, which were discovered in mushrooms, oxidized phenolic compounds to quinones leading to browning. This browning reaction, Mr. Chairman, is largely responsible for the brown coloration observed in many fresh fruits and vegetables, including mushrooms when they are cut or peeled and left to stand. It is also responsible for the chocolate brown color associated with fermented dried cocoa beans.

The initial controversy on the nature of enzymes was resolved when Louis Pasteur concluded that fermentation of sugar into alcohol was inseparable from living cells, in this case, the yeast cells he was working with, and, Eduard Buchner discovered that an extract of yeast obtained from blending yeast cells could still cause fermentation of sugar into alcohol. The principle in the yeast extract causing the alcohol production was named zymase which was later on shown to be a complex mixture of enzymes by Sir Arthur Harden. Enzyme, Mr. Chairman, is a Greek word, meaning 'in yeast' and was first proposed by Kühne in 1878. Ostwald, by 1893, demonstrated that enzymes were catalysts and their protein nature was later on proven by James Sumner. Urease from the jackbean was the first enzyme to be crystallized and by 1930, the protein nature of enzymes was firmly established when several proteolytic enzymes from the gastrointestinal track were crystallized. Purification and three dimensional structural determinations then followed. The complete synthesis of

ribonuclease, an enzyme that degrades ribonucleic acids was achieved in 1969.

GHANA COLLECTION
KNUST LIBRARY

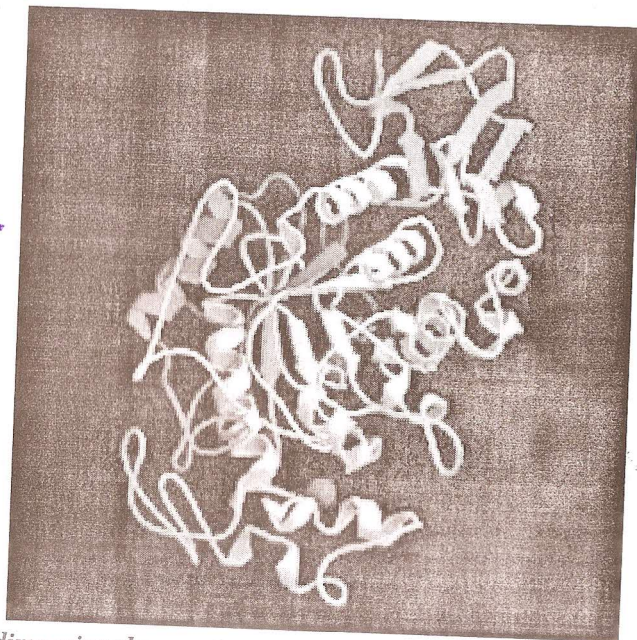


Fig. 1: 3-dimensional x-ray structure of an enzyme (Amylase)
Source: www.soul-guidance.com/health/enzymes.htm

2.1 Discovery of Ribonucleic Acid Enzymes or Ribozymes

Mr. Chairman, science is beautiful, always bringing out new knowledge through research. The monopoly enjoyed by proteins as being the only macromolecules possessing enzymatic properties for over 50 years, was dealt a serious blow upon the discovery of ribonucleic acid (RNA) molecules in the 1980s. Some RNA molecules were also shown to possess enzymatic activities. The definition of enzymes as being proteins therefore had to be modified. The RNA enzymes were named *ribozymes* in order to differentiate them from the protein enzymes. However, ribozymes have very limited activity when it comes to the range of compounds that they can act on.

Currently, over 7,000 proteins which act as enzymes are known. About 90% of all proteins found in the cell act as enzymes in nature and about 10% of these are used commercially in industries for more efficient industrial operations. For this lecture therefore, the focus is on the protein enzymes which are the real 'silent and invisible factory workers'.

3.0 HOW ENZYMES WORK

Enzymes are the biological catalysts that make processes in living organisms take place at enhanced rates. Catalysts speed up chemical reactions without themselves undergoing any net change in the process. They are able to speed up reactions to the order of million times or more because they lower the activation energy barrier needed to be overcome for a chemical reaction to occur (Zubay *et al.*, 1995).

A typical Enzyme Reaction can be represented in the illustration below:

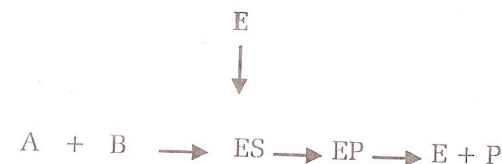


Fig. 2: A two substrate enzyme-catalyzed reaction with enzyme-substrate and enzyme-product complexes as intermediates.

A and B are the substrates on which the enzyme E acts to give intermediate complexes, ES and EP, which break down after crossing the transition state energy barrier to give a new compound P, called the product and release of the unchanged enzyme E. The substrates fit into the enzyme active sites as a key fits into a lock. In living cells, A and B could be important nutrients (substrates) such as glucose and phosphate (from ATP) which are converted to glucose - 6 - phosphate by an enzyme called hexokinase. This simple reaction, Mr. Chairman, is one of the initial processes by which energy is produced from the carbohydrate foods we eat, to enable our bodies function daily. This reaction proceeds faster than those without enzymes, for the energy of activation required to attain the transition state is greatly lowered in the presence of enzymes (Fig. 3). A

biochemical reaction will proceed only after the activation energy barrier has been crossed. Without enzymes, crossing this barrier will require strong chemical catalysts with high temperatures which no living system can endure.

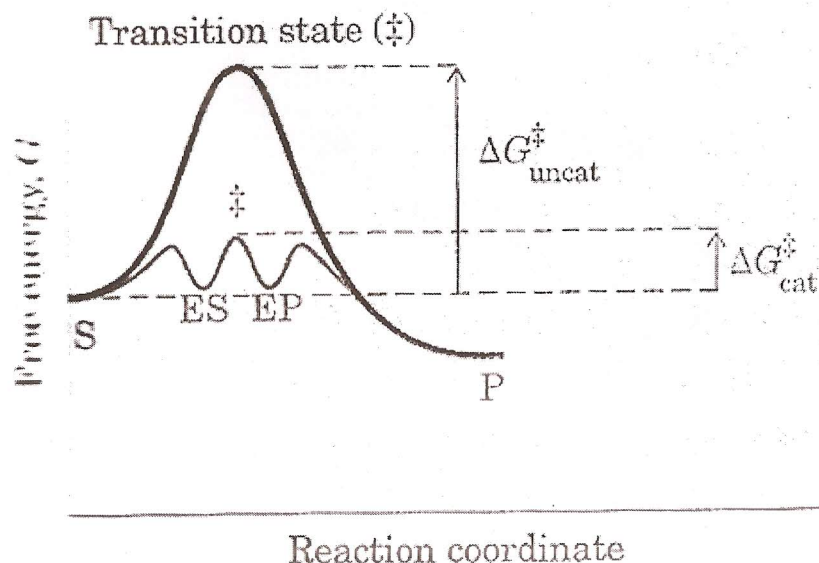


Fig. 3: Lowering of activation energy in an enzyme-catalysed reaction.

(Source: Nelson and Cox, 2008)

$\Delta G^\ddagger_{cat}$ = enzyme catalysed reaction; $\Delta G^\ddagger_{uncat}$ = uncatalysed reaction

3.1 Enzyme deficiencies and their consequences:

On a typical factory assembly line, Mr. Chairman, the absence of one single operator, e.g. person/machine which puts labels on the product, will result in a defective product. Similarly, since all life processes depend on the presence and activity of enzymes which work as a team, the absence of any of these factory workers on the assembly line of the human body can lead to problems in the individual. In the parlance of biochemistry, these are called '*inborn errors of metabolism*' and several instances exist in humans, some of which are:

- i. Absence of *Glucose-6-PO₄ Dehydrogenase* in some individuals is responsible for favism, a condition in which red blood cells begin to lyse within 24 – 48 hours after consuming faba beans which can be sometimes fatal. This is because red blood cells in humans depend totally on this enzyme to keep their integrity. Some anti-malarial drugs such as primaquine or sulfur antibiotics produce the same symptoms in such individuals.
- ii. *Albinism* in humans is due to absence of the key enzyme (*Tyrosinase*) in the synthesis of the skin pigment – melanin. The skin of such individuals is therefore devoid of melanin and we call the affected person an albino
- iii. *Lactose intolerance* is the inability to digest milk due to absence of the enzyme *Lactase* that breaks down milk sugar in the body. Such individuals experience diarrhea, bloated tummy and accumulation of gas following consumption of milk or milk products
- iv. In *Phenylketonuria*, popularly called PKU, the problem is due to the absence of an enzyme *phenylalanine hydroxylase* preventing the individual from utilizing the amino acid, phenylalanine effectively. This condition causes mental retardation in early childhood if untreated.

Aside from these few examples, there are several enzyme deficiencies in humans some of which could be fatal, since some key factory workers on the assembly line are either absent or refuse to work. In the words of Novozymes, the world's largest producer of industrial enzymes, "**Enzymes are the miracle workers of both nature and modern industry. Every time we do anything with biological materials, enzymes pave the way**" (www.novozymes.com/cgi). Thus enzymes feature prominently in our everyday activities in the home ranging from the foods we eat to the clothes we wear.

4.0 ENZYMES AS WEALTH CREATORS

While enzymes work in nature to enable life processes go on, some of their unique attributes are exploited by industries to enhance and make their operations more efficient due to the following properties of enzymes:

- They are biological catalysts that speed up biological reactions without being used up in the process
- They are specific, i.e. can only bind to certain compounds but not others even in the midst of millions of similar ones
- They work under mild conditions of temperature and pH
- Are readily destroyed (denatured) under extremes of temperature and pH.

Their use in industries demands that these same unique properties must be maintained.

4.1 Why Use Enzymes in Industries?

They offer several advantages to industries, some of which are that they:

- Increase processing rate
- Increase product yield
- Improve product texture; e.g. meat tenderization
- Reduce energy consumption due to increased processing rate and low temperature of operation
- Modify product quality to desired ones
- Develop higher value-added products from low value ones; e.g. high fructose syrup from starch.

4.2 How much wealth is generated from enzymes use by industries?

The table below shows the trend in the world enzyme market from the 1960s to present, with dramatic increases within the period.

Table 1: World enzyme market trend:

Period	Value
1960s	\$220 million
1990s	\$2 billion
2008	\$3 billion
2011 (projected)	\$6 billion

Sources: www.puribo.com ; www.highbeam.com (accessed May 21, 2009)

According to forecasts, world market for enzymes is expected to grow by 7.6% per annum. This demand will be mainly in the pharmaceutical industries as biocatalysts and also for bio-ethanol production. Novozymes has already developed enzymes for conversion of agricultural biomass (cellulose wastes) for ethanol production to be called cellulosic ethanol. Hence, commercial enzyme production alone is a multibillion dollar industry worldwide. The major beneficiaries are the food and detergent industries as shown below:

Table 2: Distribution of enzyme usage by Industries:

Type of Industry Usage	Proportion of Enzyme
Food	45%
Detergents	34%
Textiles	11%
Others *	10%

*Include leather, pharmaceuticals, pulp & paper, cosmetics, etc.

Enzyme market share for the food industry alone is forecast to reach US\$1.2 billion by 2011 www.reportlinker.com/p098340/World-Industrial-Enzymes-Market.html (Accessed May 21, 2009).

4.3 Some Specific Applications of Enzymes in Industry:

In industries, Mr. Chairman, enzymes can be used in pure forms, as crude (impure) enzymes or as whole cells, especially in food fermentation processes.

4.3.1 Enzymes in Recombinant DNA Technology:

Mr. Chairman, the euphoria and controversy that greeted the arrival of modern biotechnology, specifically genetic engineering, would not have been possible without the involvement of enzymes. Indeed, genetic engineering revolves around DNA and enzymes. There are enzymes called

Restriction endonucleases which are capable of precisely cutting a piece of DNA (called the gene) at recognized points just as an experienced seamstress cuts a piece of fabric precisely "*with no curve or bend*" (to borrow a political jargon). Then there is yet another set of enzymes, **DNA ligases**, which can, with high fidelity, join one DNA piece to another one from a different organism to create what we call a recombinant DNA. This recombinant DNA technology is the bedrock of modern biotechnology which eventually led to the generation of Genetically Modified Organisms or GMOs for short.

Restriction endonucleases and ligases are now commercially available for use by biotechnology companies for the production of GMOs as well as for research purposes, thus creating multimillion dollar industries in this area.

4.3.2 Enzymes for therapeutic uses:

In clinical practice, certain enzymes are used for therapeutic purposes; e.g. **Tissue plasminogen activator, urokinase and streptokinase** are all used to dissolve blood clots and hence widely used for treating cardiovascular disease patients. **Heparinase**, which breaks down heparin, is widely used in surgery to prevent excessive bleeding since heparin is an anti-clotting agent. **Lactase** pills are used by lactose intolerant people to enable them utilize milk and milk products. **Trypsin** and **chymotrypsin** are available as digestive aids to enable proper digestion of high protein foods.

4.3.3 Enzymes in textile production:

Advanced countries ('smart nations') use enzymes in textile manufacture to improve product quality, reduce environmental pollution as well as protect workers from chemical hazards. Starch is normally used in textile manufacture as a sizing material; (i.e. a material which will stiffen the fabric to make it easy for the designs to be imprinted on them). The starch must be removed after the designs have been imprinted before dyeing. Manufacturers normally use strong acids such as sulfuric acid for this purpose. The acids are expensive, hazardous to workers, weaken the cotton

fibres and pose environmental disposal problems to the companies. The enzyme **amylases**, which specifically act on starch, are currently used by 'smart nations' for this purpose. China, the current industrial giant has just started using enzymes in textile production in place of acids in order to cut down on the cost of pollution control (Cheng *et al.*, 2007). By this approach, their production costs go down. Is it any surprise therefore that our markets are flooded with especially their relatively cheaper textiles?

Mr. Chairman, you may not believe it, but **enzymes can make brand new clothes look very old and worn out!** The faded 'stone-washed' denim jeans, so much fancied by the youth, are now made with enzymes instead of "pumice stone" previously used for this purpose. Controlled enzyme treatment with cellulases hydrolyses the surface fibres of the dyed jean to produce the desired effect. The jean looks faded but does not get torn easily since only the surface cotton fiber is attacked by the enzyme treatment. For the youth who fancy both the faded and tattered look of their jeans, the enzyme treatment is carried out for a longer time to hydrolyse the interior fibres and partially weaken the cotton at the appropriate areas on the jeans to give it the tattered look (Fig. 4).

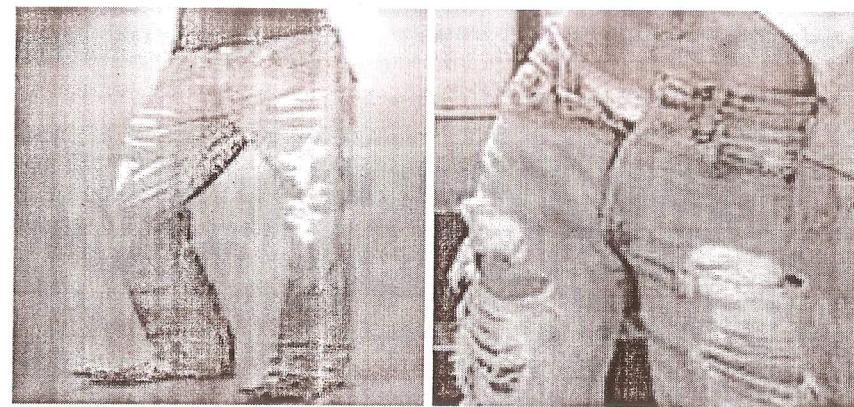


Fig. 4: Blue jeans with faded or tattered look.

(Source: www.alibaba.com/showroom/Enzyme_Washed_Denim.html)

4.3.4 Enzymes for better laundering:

Laundry clothes have different types of dirt in them, mainly protein-, carbohydrate- and fat-based dirt. For proper washing, substantial amount of soap, water, high temperature and long agitation of washing machines is necessary to have clean clothes. Incorporation of specific enzymes (mainly proteases, amylases, lipases) that can attack these substrates considerably reduces the amount of soap, water and washing time of the clothes. Additionally washing temperature is reduced since enzymes work at mild temperatures. These usually translate into savings for laundry companies. In addition, some enzymes such as *glucose oxidase*, *glycerol oxidase*, etc. are added to detergents to replace the use of chemical bleaches thus protecting the environment.

Enzymes such as cellulases are also added to some laundry detergents to remove the tiny protruding pieces of cotton fibers which make cotton clothes look dull after washing. This is called bio-polishing (polishing the clothes with biological materials).

4.3.5 Enzymes for better food processing:

This is the major area of enzyme usage currently. Many food industries in the advanced countries or 'smart' nations use enzymes in food processing to improve their production efficiency. Few examples are:

- **Bakery industries**

Currently, South African bakeries have resorted to the use of enzymes to cut down on cost of bread production. Flour manufacturers are replacing some amount of ascorbic acid in flour with enzymes which do the same work as ascorbic acid. Ascorbic acid or vitamin C was added to flour to replace potassium bromate which was banned as a flour improver. The price of ascorbic acid however became prohibitive, due to competition for it by pharmaceutical industries. The flour companies in South Africa solicited help from Novozymes out of which an enzyme, *glucose oxidase*, which provides the same function as the ascorbic acid was provided. There was overall reduction in bread production cost by about 5%. Similarly, when *lipase* enzyme was substituted for emulsifiers previously

used to improve dough strength, it led to about 40% cost reduction in bread production. Thus with the application of both enzymes in flour production, South African bakeries were able to make considerable savings in cost of bread production with enhanced profit margin (Biotimes, 2008).

- **Fish processing industries**

De-scaling (removal of scale) and de-skinning (removal of skin) of fish by some fish processing companies in some Western countries such as Norway are currently done by use of enzymes. Such fish are soaked in the relevant enzyme solution (mainly proteases) for few minutes to either remove the fish scale or the skin as the case may be. This is possible due to the specificity of enzymes since the proteases that act on fish scale or skin are different from those that will act on the fish muscle which is the edible portion. The enzyme treatment cuts down on processing time as well as amount of fish loss through mechanical processing (Ashie and Lanier, 2000) leading to increased profit margin to the companies.

- **Larger Beer from Sorghum:**

Many African countries including Uganda, Zambia, South Africa and Nigeria, now produce lager beer from 100% sorghum with the help of specific starch hydrolysing enzymes developed by Novozymes to efficiently hydrolyse the sorghum starch. With the enzyme technology, sorghum beer is produced at half the price of traditional lager beer from barley (Biotimes, 2006).

4.3.6 Enzymes for soft leather shoes and bags

Traditional leather tanning, Mr. Chairman, is one of the earliest examples of industrial uses of enzymes. To make leather soft, it has to be bated. Bating simply involves removal of non-leather proteins from the animal hide leaving behind the collagen which is the protein used for leather manufacture. Tanners used enzymes indirectly by spreading dog excreta which is a rich source of proteases for bating. The use of dog excreta is a dirty practice and an occupational hazard to workers in such factories. Thank God, currently, commercial proteases from microbial sources are now available for use in leather processing in place of the dog excreta.

KNUST LIBRARY

Aside from using enzymes for the bating process, enzymes are now available for all stages of leather processing leading to considerable economic savings in terms of energy and chemical consumption as well as reduction in environmental pollution (Biotimes, 2007).

4.3.8 Enzymes for Biofuel production

Mr. Chairman, very soon, biofuel production from agricultural biomass to be called cellulosic ethanol will become a reality. Novozymes has already developed a set of enzymes capable of digesting efficiently the cellulose biomass from forest and agricultural wastes, which can later on be fermented to produce ethanol. The research from "Laboratory to Commercialization" is currently in progress (Biotimes, 2009).

Other areas of industrial enzyme usage include:

- Drug manufacture
- Pulp and paper making
- Cosmetics, toiletries
- Mining
- Industrial effluent treatment

It is clear from the above that companies can take advantage of the benefits provided by enzymes to more efficiently manage some biological-based businesses in order to increase profit margin.

5.0 MY CONTRIBUTIONS:

5.1 Enzymes involved in lipid biosynthesis in rats

Mr. Chairman, my journey into the world of enzymes started in 1975 as a young PhD student of 25 years in Oregon State University, Corvallis, USA. In early 1968, an industrial hazard occurred in Southern Japan when polychlorinated biphenyls (PCBs) being used as an insulator in rice bran oil processing machines leaked into the oil. Over one thousand consumers of such PCB-contaminated bran oil experienced several clinical symptoms including increased eye discharge, swelling of the upper eyelids, skin pigmentations; jaundice, headache, vomiting, etc. At the molecular level, alterations in general lipid metabolism was found to be the most

important metabolic change to occur in the patients (Ishidate and Nakazawa, 1976). (Lipid is the general name for fats and oils). In experimental animals, PCBs were found to cause elevation in phospholipids and triglyceride levels. (PCBs are non-polar organic compounds and can therefore readily interact with lipids which are also non-polar). My task as a PhD student therefore, was to study the effect, if any, of PCBs on the biosynthesis (production) of phospholipids and triglycerides in rat liver and determine the mode of action of the PCBs on the enzymes involved in the process.

Mr. Chairman, phospholipid and triglyceride biosynthesis in living organisms is a complex biochemical process involving several enzymes (Fig.5). My task therefore, was to look at some selected key enzymes (6 in all) in the process in order to assess how PCBs affect these with the hope of getting some insight into the problem associated with the lipid disorders observed in the affected individuals.

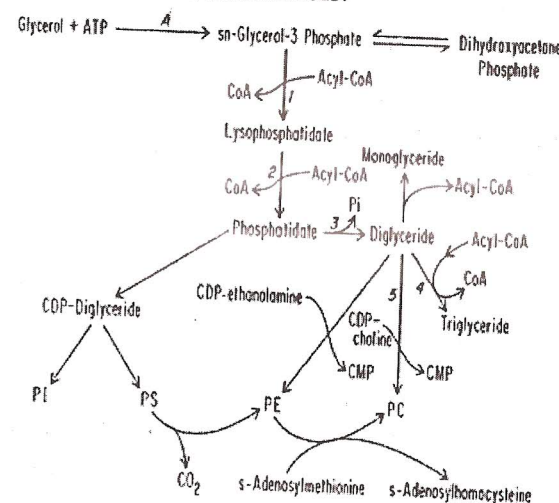


Figure 5. Pathway of phospholipid and triglyceride biosynthesis from sn-glycerol-3 phosphate.

Key: A, glycerol kinase; 1, sn-glycerol-3 phosphate acyltransferase; 2, lysophosphatide acyltransferase; 3, phosphatide phosphatase; 4, diglyceride acyltransferase; 5, phosphorylcholine-glyceride transferase.

The results of that study indicated that PCBs indeed interfered with lipid biosynthesis by altering the activities of some selected enzymes and the overall distribution pattern of lipids in many cellular organelles. The results were published in which it was explained that the elevated serum lipid levels observed with PCB-contaminated individuals may not be due to increased synthesis, but rather a decrease in lipid degradation or its slow clearance from the blood in the presence of PCBs.

That investigation formed my PhD thesis entitled: "*Polychlorinated biphenyls and related metabolites: Mode of action on phospholipid and glyceride biosynthesis*" from which two publications emerged (Dzogbefia *et al.*, 1978; Dzogbefia and Gamble, 1986).

5.2 Enzymes involved in cocoa butter biosynthesis

After working on enzymes in animals for some time, I joined an international research group during a sabbatical leave to study the activities of these enzymes in plants, specifically the cocoa plant. For one thing, it is easier to work with plants than animals. **At least plants will not protest by biting you when you try to use them for research.**

The interest in cocoa plant enzymes was due to the fact that the cocoa plant uses the same set of enzymes and reaction mechanisms studied in the rat to make cocoa butter, a very precious commodity from the cocoa industry. The objective was to find out how the cocoa plant makes its cocoa butter and identify the major enzyme in the pathway which determines how much cocoa butter can be produced by each cocoa bean. The obvious implication was to use this information to improve upon cocoa bean quality by increasing the butter content of the beans using biotechnology approaches.

Mr. Chairman, for your information, about 50% of the dry weight of an average cocoa bean is made up of cocoa butter. Hence biotechnology could be used to produce transgenic or genetically modified cocoa trees which will produce cocoa beans having more than 50% of their dry weight being made up of cocoa butter.

Indeed, the critical enzyme which the biochemists refer to as the rate-limiting enzyme in cocoa butter synthesis was identified as *diglyceride acyltransferase* (Dzogbefia *et al.*, 1993a; 1993b; 1995). My interest in this work however, was not sustained because of its possible future negative implications for the cocoa industry in producing countries. (Cocoa importing countries are likely to reduce the quantity of beans imported, but will obtain the same amount of cocoa butter needed for their processes leading to a glut in the producing countries). My focus was therefore shifted from this line of research to some other areas in the cocoa industry. This was possible, Mr. Chairman, because when I was in graduate school, a popular saying of one of my Professors was, and I quote: "***Sad indeed is the biochemist who cannot change fields***".

The training of biochemists is flexible; covering all areas of the life sciences, hence changing fields is very easy. Therefore, after working on enzymes involved in lipid biosynthesis for some time, my attention was focused on determining some of the biochemical basis of cocoa fermentation with the view of a possible future biotechnological intervention if the need should arise, having been trained earlier in industrial biotechnology.

5.3 Enzymes involved in cocoa fermentation

Mr. Chairman, as said somewhere earlier, the beauty about the use of enzymes in improving industrial processes is that they can be used in the form of pure enzymes, as impure enzymes or as whole cells whereby the cells secrete the enzymes directly into the medium of interest to enable them catalyse the relevant reactions. The use of enzymes as whole cells in food processing, for example, has been an age-long traditional process. This is what we call fermentation, which involves mainly microbiological and biochemical processes. Foods such as kenkey, beer, pito, kobi, gari, cocoa, etc., are all products of fermentation. The microorganisms spontaneously invade the food substance, multiply and secrete a number of enzymes which are the "*invisible factory workers*" able to transform the food components into the desirable ones that impart characteristic tastes and flavours associated with fermented foods.

Cocoa fermentation also involves the activities of microorganisms which spontaneously infest the cocoa beans once the cocoa pod is broken to expose the beans. The microorganisms however mainly serve as factories for producing enzymes which actually carry out the biochemical reactions during fermentation. One of these enzymes called *pectin enzymes* is involved in the initial stages of the fermentation process. It is the enzyme that is responsible for removing the sweet, slimy and pulpy material that surrounds a fresh cocoa bean before other processes of the fermentation can continue. Removal of this slimy material is crucial for proper fermentation such as the development of brown chocolate colour to occur. This enzyme can be produced by several yeasts that are normally found in fermenting cocoa (Sanchez *et al.*, 1984).

The addition of a commercial preparation of this enzyme to fresh cocoa beans in our initial investigations was found to rapidly remove the slimy pulpy material. However, if too much of the pulp was removed, the final cocoa bean at the end of fermentation was not of good quality as judged by cocoa bean quality parameters. A certain amount of pulp must remain on the beans for subsequent biochemical reactions to properly occur. The traditional cocoa fermentation normally stops before all the pulp is removed; an indication that our cocoa farmers have been applying tremendous scientific principles, though unknowingly!! The finding was published (Ansah and Dzogbefia, 1990).

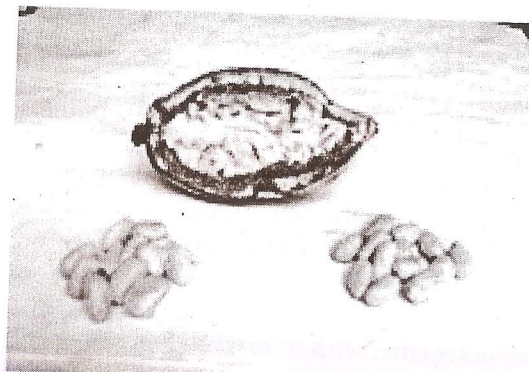


Fig. 6: Fresh cocoa beans with (R) and without (L) pectin enzyme treatment.

Attention was focused on one of the yeasts which produce these pectin enzymes to study the type of enzyme produced. We were able to identify the particular type of pectin enzyme produced by this yeast strain (*Saccharomyces cerevisiae* ATCC 52712) as *polymethylgalacturonase* (Dzogbefia *et al.*, 1999). Subsequently, this yeast has served as a source of pectin enzyme production in our laboratory because of its many industrial applications (Biotimes, 2006).

5.4 Pectin enzymes and their role in food industries

Mr. Chairman, pectin enzymes can be defined as a group of enzymes found in plants and microorganisms that collectively act on pectin to break it down into its individual components.

What is pectin?

Pectin is a type of plant polysaccharide found in plant cell walls and is normally responsible for the firmness of unripe fruits and vegetables. When fruits and vegetables begin to ripe, this rigid structure is degraded by the action of pectin enzymes thus enabling the fruits or vegetables to soften releasing their liquid contents, called fruit or vegetable juices. Without the action of these pectin enzymes, one will not be able to squeeze any juice from a ripen fruit or vegetable, since the liquid which is mainly water is held tightly in association with the pectin present in the fruit. It is only when the pectin is degraded that the water is freely released. In nature however, the endogenous enzymes cannot totally degrade all the pectin in a fruit or vegetable; some residual pectin still remains un-degraded, thus making it impossible for all the juice to be extracted from a fruit without the aid of an exogenous source of the enzymes (Biotimes, 2006).

5.4.1 Importance of pectin enzymes in industry

Mr. chairman, from the brief definition and description given above, it must be clear at this point that pectin enzymes may play some tremendous roles in the fruit and vegetable processing industries. Indeed, fruit and vegetable juice producers in the advanced countries ("smart nations") all rely heavily on the use of pectin enzymes to more efficiently carry out

their processes. The application of the enzymes in fruit processing for example, offers the following advantages:

- They increase rate of juice extraction
- Give higher juice yield
- Reduce energy consumption during extraction
- Enhance extraction of color into juice
- Cause rapid clarification of a cloudy juice such as apple juice
- Produce drier spent pulp with reduced disposal cost

All the above advantages ultimately translate into more profit for the companies. Our fruit processing industries in Ghana are not familiar with the use of enzymes in processing. A survey carried out in 2004 (unpublished results) showed that most of the fruit juice producers in Ghana operate rather inefficiently with low juice yield. One industry which was found to have attempted the use of pectin enzymes in its operation abandoned it because of the difficulty in keeping the enzyme active after it has been purchased and brought into the country, due mainly to our power fluctuations.

Thus for our local fruit juice processing industries to benefit from enzyme technology, the enzymes must be locally produced and able to work under our environmental conditions as those imported.

5.4.2 Local production of pectin enzymes from *S. cerevisiae* (ATCC 52712)

As indicated earlier, the yeast, *Saccharomyces cerevisiae* (strain ATCC 52712) was found to be a good source of this enzyme. The last 16 years or so have been devoted to producing this enzyme locally in our laboratory and testing its activity in many applications. The yeast enzyme has several advantages viz:

- i. Works in a broad pH range normally found in most fruits, thus requiring no pH adjustments
- ii. Works under broad temperature range of 30° – 55° Celsius, where most of our industries operate
- iii. Remains active at refrigerator temperature for several days
- iv. Can easily be produced on demand

- v. Can be produced using many fruit juices as medium for the yeast growth
- vi. The yeast is readily available and easy to culture

So far, the enzyme has been produced with reasonable activity in the following fruit juices:

- i. Orange juice
- ii. Pineapple juice
- iii. Papaya juice
- iv. Mango juice

5.4.3 Laboratory Trials

The enzymes produced in pineapple and papaya juices were used to test their efficacy in pineapple and papaya juice extractions respectively in the laboratory with very positive results. The addition of the enzyme (0.02%) to pineapple pulp resulted in about 65% faster extraction rate compared to those without enzyme addition and about 6% increase in juice yield. The major impact of the enzyme treatment was therefore on the more rapid rate of juice extraction leading to less consumption of energy through mechanical pressing. The reduced energy consumption could be translated into increased profit margin to the processor.

Regarding papaya juice extraction, the effect of the enzyme treatment was more dramatic: there was 85% increase in extraction rate with an overall 35% increase in total volume of juice obtained. However, volume of free-run juice increased by as much as 180% upon enzyme treatment, indicating that after the enzyme treatment, there was virtually very little juice left to be pressed out. This again reduces the energy consumption drastically with reduction in processing cost.

Free-run juice, Mr. Chairman, is the juice that normally comes out of a fruit when it is being peeled with no extra pressure exerted. Thus when pectin enzyme is added to a fruit, most of the juice will ooze out without any pressing, leaving very little to be pressed out mechanically and this

cuts down on electricity consumption. These results are summarized below:

Table: 3. Effect of pectin enzyme application in extraction of pineapple and papaya juices.

Fruit Type	Increase in extraction rate over controls	Increase in vol. of free-run juice	Increase in total juice volume
Pineapple	65%	—	6%
Papaya	85%	180%	35%

The findings have been published (Dzogbefia and Djokoto, 2006a; 2006b; Djokoto *et al.*, 2006)

5.4.4 Industrial trials

The essence of research, Mr. Chairman, is to bring some benefit to society. The findings from this study were therefore extended to some pineapple juice producers in and around Accra where earlier surveys were carried out. The essence was to see whether the results obtained in a laboratory setting could equally be applicable on an industrial scale.

Working in collaboration with five small-scale commercial pineapple juice producers in Accra and Nsawam, the enzyme produced in the laboratory was used in their processing. The outcome of this test, Mr. Chairman, was that the conditions established in the laboratory were able to increase the yield of pineapple juice extracted significantly. As enzyme dosage was increased from zero, there were corresponding increases in volume of juice obtained at all the participating companies.

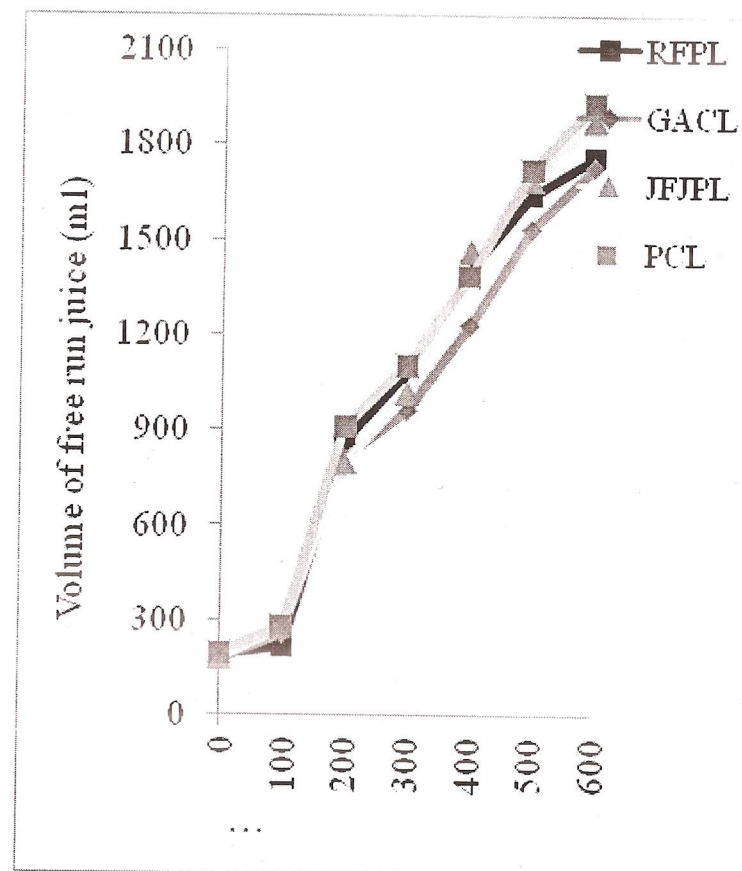


Fig. 7: Effect of increasing enzyme dosage on volume of free-run juice*

(* Different notations denote different participating fruit juice industries in the trial)

This translated to an average of about 70% increase in volume of free-run juice obtained over the controls with enzyme treatment.

The benefit of pectin enzymes was equally exploited in the production of cassava starch by traditional starch processors. Cassava roots also contain some amount of pectin which binds the starch granules in the cell making its release difficult unless the pectin network is broken. Laboratory trials showed an increase in yield of starch of 60% after enzyme treatment. Working in collaboration with a local starch producer at Amakom in Kumasi, the enzyme produced in the laboratory was applied to large scale starch extraction with good outcome. On the whole, there was a 46% increase in yield of starch obtained and 50% faster rate of extraction.

Table 4: Effect of pectin enzyme treatment on cassava starch extraction

Experimental Condition	Increase in starch yield	Increase in rate of starch extraction
Laboratory Trial	60%	54%
Industrial Trial	46%	50%

Traditional starch extraction, Mr. Chairman, involves a waiting period for the extracted starch to settle under gravity. The settling process can be very long. With the application of the enzyme, the rate of settling was increased by 50%. Therefore in principle, one and a half times as much starch could be processed within the same time period when the enzyme technology is adopted. The quality of the starch for industrial uses was also not affected by the enzyme treatment when analysed. The results of this work have also been published (Dzogbefia *et al.*, 2008a; 2008b).

The adoption of the enzyme technology by the industries involved in the trials rests on a modification of their processing machines to allow some time for enzyme to be in contact with the substrate in order to work effectively on it. This step has not yet been taken by any of the industries.

6.0 MUSHROOM BIOTECHNOLOGY AND ROLE OF ENZYMES IN THE FERMENTATION PROCESS

Mr. Chairman, as a result of my training in mushroom biotechnology in Germany, some other areas of my research involve the indirect use of

mushrooms as sources of enzymes to add value to the abundant agricultural and industrial wastes in our environments.

Two areas of interest currently are:

- Cultivation of edible mushrooms on common agro-wastes
- Nutritional improvement of agro-wastes for use in animal feed.

6.1. Mushroom production on common agricultural wastes

Mushrooms have been considered as delicacies in many cultures including African cultures. Mushrooms appear naturally in our forests and grasslands when the environmental conditions are conducive. It used to be very common for rural folks to go mushroom hunting during the rainy season. However, the range of mushroom species that can be picked naturally from the wild has dwindled considerably due to environmental degradation. The current practice therefore is to use biotechnological interventions to produce certain types of mushrooms all year round. In addition to mushrooms being very rich sources of nutrients, their cultivation is also a means by which the environment is protected since all the materials on which mushrooms are grown are composed of agro and industrial wastes. In the words of a renown mushroom scientist, "the task of any mushroom farmer is to put grass or farm residues on your dining table as food" (Zadrazil, Personal communications, October 1992, Braunschweig, Germany).



Fig. 8: Grass as food on dining table

Enzymes are indirectly involved in mushroom cultivation. In mushroom cultivation, Mr. Chairman, after the substrate (sawdust, cocoa pod husk, cassava peels, corn cobs, etc.) on which the mushroom will be cultivated is prepared, a mushroom seed called spawn in mushroom science is then added to the surface of the substrate. The spawn is synonymous with seed of a food crop to be sown in the soil. The spawn, being a seed, will initially utilize the little nutrient in these agro-wastes to germinate. After germination, it will quickly secrete a range of enzymes that will enable it to degrade the complex materials in the substrate into simple soluble ones for its growth. Enzymes such as cellulases, hemicellulases, lignases and tannases will be secreted by the mushroom fungus into the substrate. These range of enzymes therefore break down the complex materials and the mushrooms in turn begin to utilize these to enable them grow rapidly as a network of strands called mycelia which will totally colonize the substrate to form a whitish substance (Fig. 9).

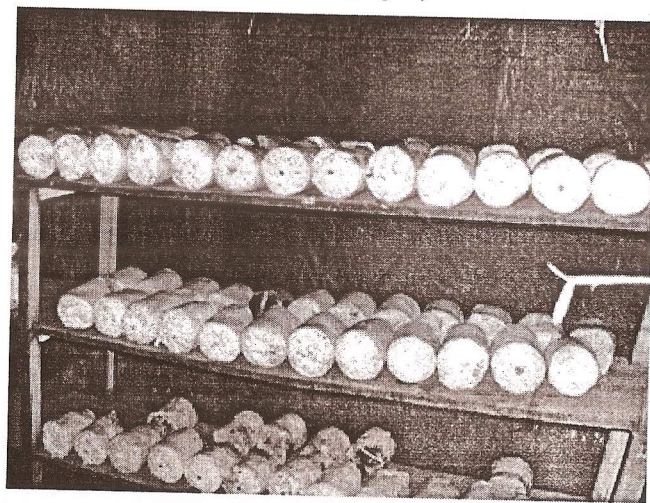


Fig. 9: Mushroom substrate fully covered with mycelia network

GHANA COLLECTION
KNUST LIBRARY

When the mycelia network is stimulated by exposure to an environment with oxygen and high moisture, they develop into fruiting bodies that we call mushroom which can be harvested for food. It is therefore clear that enzymes play a major role in this area of agriculture. This is an example of using enzymes as whole cells for food production, in this case called *solid state fermentation*.

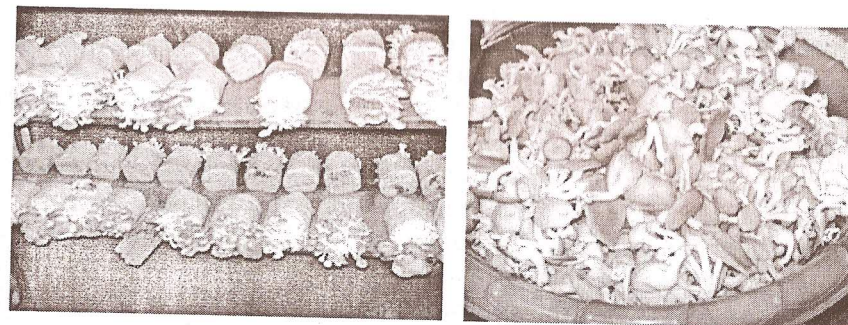


Fig. 10: Mushroom fruiting bodies (A) and harvested mature mushrooms (B)

In our work on mushrooms over the years, we have experimented on the use of different agricultural wastes as possible substrates to grow oyster mushrooms. Commercially, in most countries, including Ghana, oyster mushrooms are cultivated using sawdust as the most convenient substrate. The disadvantages of the sawdust method, Mr. Chairman, are many, including:

- Long composting/Pretreatment periods of 28 – 42 days
- Requirement for some chemical additives to the substrate
- Sawdust availability mainly in the forest areas only.

Compared to sawdust, other materials such as cassava peels, corn cobs, cocoa pod husk, etc. require only 3 – 8 days pretreatment period and need no chemical addition. Therefore, all things being equal, it is possible to grow 4 – 5 cycles of mushrooms using these substrates compared to sawdust. Besides, these substrates are readily available in many rural

LIBRARY
KWAME NINSINAH UNIVERSITY OF
SCIENCE AND TECHNOLOGY

communities, making it possible for rural dwellers to use these for backyard cultivation of mushrooms to enrich their diets.

Our work has shown that aside from the yield being comparable to that on sawdust, the physical quality of the mushroom on some of these alternative substrates such as cassava peels was better than those grown on sawdust.

6.2 Bioconversion of agricultural wastes into value added products using mushrooms as enzyme sources

Using fungi such as mushrooms to convert agro-wastes into better animal feed is currently an important ongoing biotechnological practice. The major cost of poultry production is due to the feed ingredients, mainly maize and protein sources. Unlike ruminants such as cattle, goats, etc., poultry cannot effectively use agricultural wastes such as grass, sawdust, cocoa pod husk, etc. as feed ingredients since they lack the requisite enzymes in their digestive system to break down the roughage into the needed nutrients. In advanced countries, poultry feeds are made with the addition of commercial enzymes to improve the feed quality and digestibility leading to more efficient meat and egg production.

One of our current research foci therefore was the indirect use of enzymes as whole cells to convert cheap and abundant agro-wastes into more nutritious feed for use in the poultry industry. Specifically, we have been treating cocoa pod husk and cassava peels with the oyster mushroom to partially convert the non-digestible fibre components of these wastes into products that can easily be assimilated by the birds. By this approach, it is possible to reduce the amount of corn used in poultry feed formulations which will lead to some reduction in the cost of feed.

Work done so far indicated that cocoa pod husk and cassava peels nutrient composition improved considerably after their fermentation with the oyster mushroom for 5 or 6 weeks (Alemawor *et al.*, 2009; Adu, 2009). The mushroom was capable of secreting various enzymes which could break down the fibre components, namely, cellulose, hemi-cellulose and lignin into soluble sugars that the birds can easily assimilate for their growth.

We therefore observed significant reductions in the levels of these fibre components after the mushroom treatment (Fig. 11). In addition, the fermented products have their tannin contents drastically reduced (Fig. 12) while the protein and carbohydrate levels increased after fermentation. Tannins in animal feed are able to bind the proteins making them unavailable to the animal concerned. With their reduction by the treatment, the feed protein will be fully available to the birds.

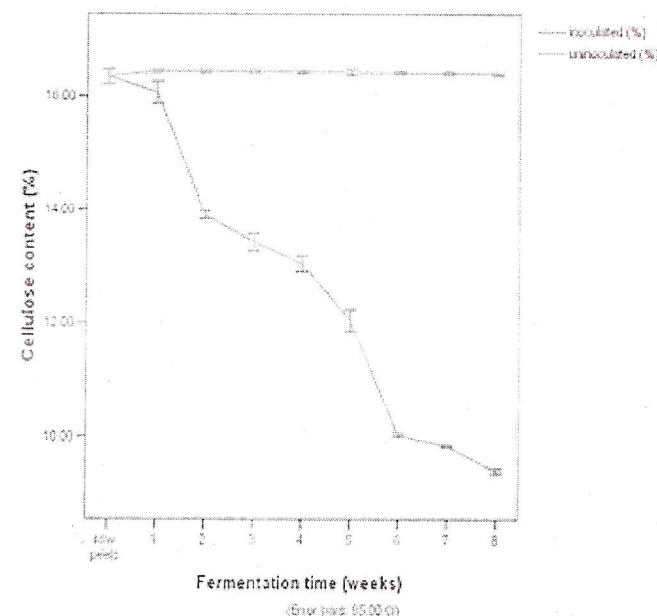


Fig. 11: Decline in cellulose during fermentation of cassava peels

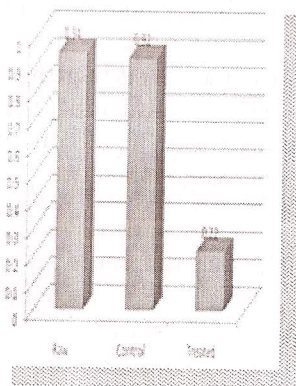


Fig. 12: Changes in tannin content following fermentation of cassava peels with mushroom

Feeding trials using some of these bio-processed agricultural wastes showed that replacement of up to 20% corn with mushroom-processed cocoa pod husk, for example, posed no adverse effect to the growth of broiler birds. Treating the cocoa pod husk with the mushroom before use in feed formulation gave better results than using the untreated pod husk (Donkor *et al.*, 1991; Atuahene *et al.*, 1984.). Additionally, the oyster mushroom fermented cocoa pod husk performed better in broilers than those birds which were fed the same cocoa pod husk treated with commercial enzymes supplied by Novozymes.

A 20% corn replacement with processed cocoa pod husk could reduce the overall cost of the feed while adding value to an underutilized agro-waste. It is important to note that in this technology, the mushrooms must not be allowed to develop into fruiting bodies after the spawn-run time, else they themselves will begin to utilize some of the nutrients initially produced (Fig. 13).

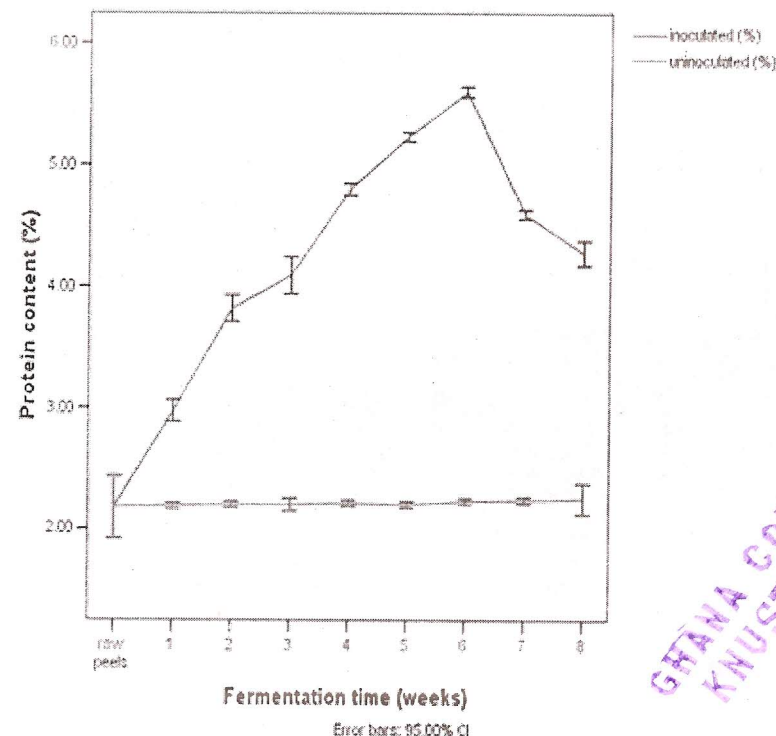


Fig. 13: Decline in protein content of cassava peels after optimum fermentation period (stage of mushroom appearance)

It is possible for small scale cottage industries to be created from this technology, e.g.

- Cocoa pod husk processing industries could be set up around the cocoa plantations to collect cocoa pods, mill and dry the milled products;
- Small-scale fermentation industries to purchase the dried and milled products for bio-processing for sale to feed millers.
- Poultry feed mills using the processed husk in poultry feed formulations

This technology is becoming very important in many developing countries now to enable the utilization of the abundant plant wastes in the environment for conversion into value-added products.

Mr. Chairman, the foregoing discussions on my involvement in the enzyme world clearly show that we do not always need sophisticated technologies in order to exploit enzymes for our national development. Exploiting enzymes in the pure form, impure form or as whole cells in fermentation, can enable us add value to some of the abundant agricultural wastes available in our backyards as has been demonstrated in this lecture.

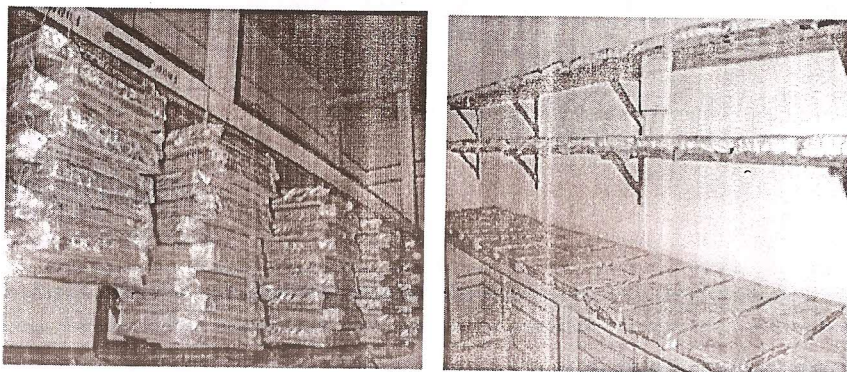


Fig. 14: Low-cost technology for fermentation of agro-wastes into animal feed

7.0 RECOMMENDATIONS

Perhaps, the following recommendations may be worth considering with regards to the Ghanaian situation:

- i. There is need for development of home grown technologies for enzyme production and application by screening and isolating enzymes from our indigenous microbes.
- ii. Production and applications of industrial enzymes have been integrated into the Biochemistry and Food Science syllabi. Facilities for pilot plant demonstrations can convince industries on the benefits of the technology. The setting up of these facilities

in the two Departments for demonstrations to both students and entrepreneurs is proposed.

- iii. Need to encourage industries to occasionally take some calculated risks by accessing new technologies to improve upon their operations is essential, as help, in terms of consultancy will be available to them. The cost of using commercial enzymes are easily offset by the benefits to be derived thereof.

8.0 CONCLUDING REMARKS

Mr. Chairman, for over an hour or so now, I have tried to espouse the virtues of application of enzymes in industries to create wealth. They are the "silent and invisible factory workers" that are found in every nation on planet earth including Ghana.

The world is advancing fast; new ways of doing business is the order of the day. Information and communication technology is having tremendous impact on the way companies go about their businesses. Exclusive to the biological world, is the new wave of technology called biotechnology. Enzymes have taken centre stage in biotechnology applications across the globe. Virtually every business having something to do with biological materials is resorting to exploiting the unique properties of enzymes to enhance its operations for wealth creation. Can Ghana afford to stand and stare?

The advantages of enzyme use in food processing have been amply demonstrated, at least to some fruit juice and cassava starch processors in the country. The adoption of the technology however, is a matter of choice with the participating industries.

However, Mr. Chairman, Dr W. Paddolina once said and I quote: "*Technological backwardness is not accidental; it is a result of conscious choice*". (Paddolina, 2004).

I will thus conclude this lecture and profess that: Enzymes are all around us in the environment – in plants, animals and microorganisms, and can bring great wealth if a nation is 'smart' enough to exploit them for technological advancement.

Mr. Chairman,
Distinguished Ladies and Gentlemen,
My deep appreciation goes to all my graduate students for their contribution of data for this lecture. I also wish to thank Prof. J.H. Oldham, Prof. W.O. Ellis and Mr. K. Nsiah, who read through the lecture and made useful

GHANA COLLECTION
KNUST LIBRARY

suggestions. I am most grateful to you all out there. Thank you all for your kind attention and God richly bless us all!

REFERENCES

Adu, D. (2009). Conversion of cassava peels into nutritious animal feed by fermentation with the oyster mushroom (*Pleurotus ostreatus*). MSc. Thesis, Department of Biochemistry and Biotechnology, Kwame Nkrumah University of Science and Technology, Kumasi.

Alemawor, F., V.P. Dzogbefia, J.H. Oldham and E.O.K Oddoye (2009). Effect of *Pleurotus ostreatus* fermentation on cocoa pod husk composition: Influence of fermentation period and manganese ion supplementation on the fermentation process. *Afr. J. Biotech.* **8** (9) 1950-1958

Ansah F. and Dzogbefia V.P. (1990). The role of microbial and endogenous enzymes in cocoa fermentation. *J. Univ. Sci. & Tech.* **10** (2), 69-73.

Ashie, I. N. A. and Lainer, T.C. (2000). Transglutaminases; In: Seafood Enzymes ed. N.F. Haard and B.K. Simpson. Marcel Dekker Inc. New York pp. 147-168.

Atuahene, C.C., Adams, C. and Adomako, D. (1984). Cocoa pod husk in starter diets of broiler chickens. In: Cros, E. (ed.) *Proc. 9th Int. Cocoa Res. Conf.* Lome, Togo, 12-18 Feb. 1984. Cocoa Producers' Alliance London, pp. 495-500.

Biotimes (2008). Clear advantages with new generation Pectinex Mash. *Biotimes* No. 2 June 2008, pp 3-4

Biotimes (2008). South African Bakeries fight rising costs with enzymes. *Biotimes* No. 3 Sept. 2008, pp. 6-7.

Boustead, C. and Walker, J.H. (1991). Annexins, calcium-dependent phospholipid binding proteins. In: Cellular Calcium, Practical Approach. (Eds. J.E. McCormack and E.H. Cobbold, Oxford University Press, Oxford.

Cheng, J. Wang, Q., Hua, Z. and Du, G. (2007). Research and application of biotechnology in textile industries in China *Enz. Microb. Technol.* 40 (7) 166.

Djokoto, D., V. P. Dzogbefia and J.H. Oldham. (2006). Rapid extraction of pawpaw juice with the application of locally produced pectic enzymes from *Saccharomyces cerevisiae* (ATCC 52712) *Food Biotechnology* 20, (1) 31 – 41.

Donkor, A., Atuahene, C.C., Wilson, B.N. and Adomako, D. (1991). Chemical composition of cocoa pod husk and its effect on growth and feed efficiency of broiler chicks. *Anim. Feed Sci. Technol.* 35 : 161-169.

Dzogbefia, V.P. (1979). Polychlorinated biphenyls and related metabolites: Mode of action on phospholipids and glyceride biosynthesis. PhD Thesis, Oregon State University, Corvallis Oregon, USA.

Dzogbefia, V.P. and Fritz, P.J. (1993). Cocoa seed lysophosphatidate acyltransferase. *Proc. 11th Int. Cocoa Res. Conf. Cocoa Producers Alliance, Lagos.* pp. 841-845.

Dzogbefia, V.P., McHenry, L. and Fritz, P.J. (1993). Developmental studies of cocoa seed tricylglycerol biosynthesis. *Proc. 11th Int. Cocoa Res. Conf. Cocoa Producers Alliance, Lagos.* pp. 847-852.

Dzogbefia, V.P. and Fritz P.J. (1995). Subcellular distribution of cocoa (*Theobroma cacao* L) seed phosphatidate phosphatase: role of Cytoplasmic versus microsomal enzyme in cocoa butter biosynthesis *J. Biochem. Biotechnol. & Mol. Biol.* 3, 38-45.

GHANA COLLECTION
KNUST LIBRARY

Dzogbefia, V.P., Ameko, E., Oldham, J.H. and Ellis, W.O. (2001). Production and use of yeast pectolytic enzymes in pineapple juice extraction. *Food Biotechnology* 15 (1) 29-39.

Dzogbefia, V.P. and Djokoto, D.K. (2006). Combined effects of enzyme dosage and reaction time on papaya juice extraction with the aid of pectic enzymes - a preliminary report *J. Food Biochemistry* 30, 117-122.

Dzogbefia, V.P. and Djokoto, D.K. (2006). Comparison of physico-chemical and sensory characteristics of pawpaw juice extracted with locally produced and commercial pectin enzymes. *Journal of Science and Technology* 36 (3) 59-65.

Dzogbefia, V.P., Ofosu, G.A. and Oldham, J.H. (2008). Evaluation of locally produced *Saccharomyces cerevisiae* pectinase enzyme for industrial extraction of starch from cassava in Ghana. *Scientific Research and Essays* 3 (8), 365-369.

Dzogbefia, V.P., Ofosu, G.A. and Oldham, J.H. (2008). Physico-chemical and pasting properties of cassava starch extracted with the aid of pectin enzymes produced from *Saccharomyces cerevisiae* ATCC 52712. *Scientific Research and Essays* 3 (9) 406-409.

Ishidate, K. and Nakazawa, Y. (1976). Effect of polychlorinated biphenyls (PCBs) administration on phospholipids biosynthesis in rat liver. *Biochem. Pharmacol.* 25, 1255-1260.

Nelson, D.L. and Cox, M.M. (2008). *Lehninger Principles of Biochemistry* 5th edition. W.H. Freeman and Co. New York. pp. 187.

Nsiah, K. (2005). *Enzymes: Delicate and intricate catalytic molecules for undergraduate biochemists and allied life sciences.* Narco Printing Works, Asafo – Kumasi pp. 2-4.

LIBRARY
KWAME N. RUMAH UNIVERSITY OF
SCIENCE AND TECHNOLOGY
KUMASI-GHANA