Everyday SCIENCE For Schools

Volume 12, Number 1, 2023

"Our daily diet has a significant role to play in our wellbeing by suppling the body with all the essential nutrients required" - Narh *et al*

“Our daily diet has a significant role to play in our wellbeing by suppling the body with all the essential nutrient required” - Narh et al

Table of Contents

Editorial Board

Editorial Disclaimer:

Articles and imagery in this Magazine apart from those referenced, are the sole responsibility/views of their respective authors.

Ghana Science Association

Introduction

The Ghana Science Association (GSA), a voluntary, non-profit making and multidisciplinary organisation of scientists, technologists and mathematicians was formed in 1959. The Association traces its origin to the West African Science Association (WASA) which was formed in 1953 at the University College of the Gold Coast. WASA was formed to provide West African scientists the forum to advocate the importance of Science and Technology as a necessity and bedrock for national development. The formation of GSA broadened the scope of activities from reading of scientific papers to involvement in national and international affairs. The Association was placed on government subvention under the Ministry of Education as far back as 1961 by a Presidential Fiat. Hence the Association is supported through a budgetary allocation from the Ghana Government. Other sources of income include membership dues and proceeds from workshops and conferences. The GSA was mandated to promote, popularize and demystify science and create a scientific culture in the country. The Association has made tremendous contributions to National Development, Health and Economic Growth through scientific interventions. The Secretariat is a point where scientific and technological information and research findings are obtained by individuals and corporate bodies.

Membership of the Association is drawn from the Universities, Research Institutes, Industry, Government and Persons interested in the promotion of Science and Technology.

Vision and Mission

Vision

To become a dominant voice in Science and Technology advocacy by promoting and popularizing Science and Technology to meet national developmental needs.

Mission

Advancing Science, Technology, Engineering and Mathematics (STEM) through interaction and cross-fertilization of ideas of all interested people to: -

1. Popularize, promote and disseminate scientific information and technology transfer for national development.
2. Contribute to the development of National Science and Technology policy.
3. Collaborate with industry to set national research agenda.
4. Establish linkages with industry to promote the transfer and application of Science.
5. Seek affiliation and foster cooperative links with other national and international organizations.

Activities

1. Organization and participation in scientific conferences, workshops, seminars, symposia, public lectures, quizzes and science fairs.
2. Promotion of carrier development of scientists in Universities and Research Institutes in Ghana and elsewhere.
3. Publication of the scientific journal, magazines and books (e.g. Journal of the Ghana Science Association and Everyday Science for Schools magazine).
4. Training programmes for mathematics and science teachers to improve the teaching and learning of these subjects in Schools and Colleges of Education.

Contribution to National Development

Issues of national importance have been regularly and consistently highlighted at biennial workshops, conferences etc. Communiqués had been submitted to Government and other stakeholders on very topical themes to help shape national policies.

THE ARTICLES

THE CHOCOLATE CHRONICLES: FROM BEAN TO BAR, UNVEILING THE SWEET ALCHEMY AND INTRICATE JOURNEY OF CRAFTING TEMPTATION

Attipoe Korkoe Yao (BSc.)
Institution: *Department of Food Science and Technology, KNUST*
Email: *attipoekorkoe@gmail.com*

Introduction

For generations, this exquisite treat has delighted taste buds all around the world, from velvety milk chocolate to rich black chocolate. But have you ever wondered what happens when ordinary cocoa beans are transformed into the delectable treat known as chocolate? Chocolate production is an enthralling combination of art, science, and workmanship that takes us from the tropical jungle where cocoa trees thrive to the chocolate morsels and bars that line store shelves.

This article underlines a delectable journey through the numerous stages involved in chocolate making, revealing the mysteries behind this renowned dessert. Prepare to be pampered as we explore the world of cocoa, roasting, and the alchemical process that transforms these simple beans into a delicacy enjoyed by millions. Let us explore the fascinating process of making chocolate, from bean to bar.

Background and History

Chocolate has a fascinating history that dates back thousands of years. Its origins can be traced back to Mesoamerica's ancient civilizations when it held considerable cultural and culinary significance. The Mayans and Aztecs were among the first civilizations to cultivate cacao trees and enjoy chocolate in various ways. Chocolate was regarded as a sacred and valuable item in these early civilizations (Lima *et al.,* 2011). It was frequently utilized in religious rites and as a form of cash in trade. The Mayans developed a bitter beverage called "xocoatl" out of pulverized cacao beans, water, and spices. They thought the elixir has heavenly and revitalizing characteristics (Vos *et al.,* 2003) (Pohlan *et al*., 2006).

When the Aztecs rose to power, they carried on the Mayans' chocolate heritage and improved it. They equated chocolate with fertility and thought it has aphrodisiac properties. The Aztec monarch Montezuma II was known to eat massive amounts of xocoatl on a daily basis, believing it to be a drink for the gods. The 15th-century contact between Mesoamerican cultures and European explorers brought chocolate to the notice of the rest of the world. Conquistadors from Spain, especially Hernan Cortes, encountered the Aztecs and were introduced to their valuable cacao beans. The unique beverage captivated the Spanish, who took

cocoa beans back to Europe (Shafi *et al.*, 2018) (Wood, 1985).

Initially, chocolate was considered a luxury by European royalty and clergy. The bitter cacao drink was sweetened with sugar and spiced with vanilla and cinnamon. It gradually grew in popularity and spread over Europe, becoming a favourite beverage associated with social gatherings and decadence. The 18th-century Industrial Revolution changed chocolate manufacture. The development of steam-powered machinery and new processing processes enabled larger-scale production of chocolate (Poelmans & Swinnen, 2016). The introduction of the cocoa press in the nineteenth century enabled the separation of cocoa butter from cocoa solids, resulting in the manufacturing of natural cocoa powder, cakes, solid chocolate bars, and so on.

Chocolate has evolved and diversified throughout its history, with different regions and cultures developing their own chocolate traditions and delicacies. Today, chocolate holds a significant place in both cultural and culinary contexts around the world, as a symbol of indulgence, comfort, and pleasure capable of transcending language and cultural barriers.

Growing and Harvesting Cocoa

The first stage of chocolate production involves the cultivation and harvesting of cocoa beans, which are the key ingredient in chocolate. Cocoa is primarily grown in regions such as West Africa, specifically Ghana, Ivory Coast, Nigeria, and Cameroon, Latin America (including countries like Brazil, Ecuador, and Peru), and parts of Asia (such as Indonesia and Malaysia) (Vos *et al.*, 2003) (Dimtry & IBIS World, 2021).

Cocoa trees grow in tropical regions, often within 20 degrees of the equator's north and south poles. These areas have optimum growing conditions for cocoa due to a mix of rainfall, temperature, and soil type. The trees require a warm, humid climate with temperatures ranging from 21 to 32 degrees Celsius and an annual rainfall of 1,500 to 2,000 millimeters. Planting cocoa seeds, which are often found within cocoa pods, is the first step in the cultivation process. Farmers select healthy pods from mature cocoa trees and extract the seeds with care. The seeds are then planted directly in the soil or in nurseries, where they germinate and grow into young cocoa trees (Kuusaana *et al.*, 2021) (IDH, 2021).

Cocoa trees are members of the *Theobroma cacao* species and come in a variety of types, the most prevalent of which are *Criollo*, *Forastero*, and *Trinitario*. Each cultivar has a different flavour profile and personality. *Criollo*, for example, is recognized for its delicate flavour, *Forastero*, for its robustness, and *Trinitario*, a hybrid that combines qualities from both species. When cocoa trees achieve maturity, they begin to produce cocoa pods. These elongated, football-shaped fruits sprout directly from the tree's trunk or branches. Depending on the type, the pods can range in color from yellow, orange, or red to dark purple or green (Pohlan *et al.*, 2006).

Cocoa pod harvesting is a time-consuming and labour-intensive activity. Farmers use machetes or specialized instruments to carefully cut the ripe pods from the trees. Identification of the proper stage of maturity needs expertise and knowledge, as under-ripe or overripe pods may not yield high-quality beans. The cocoa pods are opened after harvesting to remove the cocoa beans. Mucilage is a delicious pulp that surrounds the beans. Some farmers ferment the beans for several days in shallow pots or wooden boxes (Lima *et al.*, 2011).
In the cocoa sector, sustainable farming strategies such as agroforestry and organic cultivation methods are gaining traction. They encourage biodiversity, safeguard the environment, and help cocoa producers make a living. Initiatives are being launched to secure fair trade and enhance farmers' working conditions and earnings, with the goal of creating a more equitable and sustainable cocoa sector (Vos *et al.*, 2003).

Fermentation and Drying

Fermentation and drying are critical phases in the chocolate manufacturing process once the cocoa pods are harvested. These stages are critical for generating chocolate's distinct flavours and aroma. Once harvested, the pods are gently opened to retrieve the cocoa beans inside. The beans are extracted and gathered while still encased in the delicious pulp or mucilage. As previously noted, the extraction technique needs the skill to avoid harming the beans.

The cocoa beans, together with the surrounding pulp, are placed in containers or fermentation boxes after extraction. These containers allow for air movement and a microbially friendly atmosphere. The beans are fermented for a set amount of time, which might range from a few days to a week. Fermentation is an important step in the chocolate-making process. Natural yeasts and bacteria found in the pulp trigger a series of metabolic events during fermentation. These interactions generate heat and cause the pulp to degrade, resulting in a favorable environment for the creation of chocolate's rich flavours and aromas (Ministry of Food Production, 2013) (De Vuyst & Weckx, 2016).

Changes occur within the cocoa beans as a result of the fermentation process. Bean enzymes break down proteins and carbs, turning them into simpler molecules. This procedure decreases the beans' bitterness and astringency while increasing the favourable taste precursors. Physical changes occur in the beans as fermentation occurs. They deepen in colour and emit a distinctive chocolate flavour. The tastes start to emerge, with variations ranging from fruity and floral to nutty and earthy depending on elements such as cocoa variety and fermentation circumstances (Ackah & Dompey, 2021).

When the fermentation process is finished, the beans are removed from the fermentation tanks and readied for drying. The beans, which are still partially coated with pulp, are spread out in a single layer on drying trays or mats. They are left to dry naturally, usually in the sun, however, some places use specialized drying processes. Another important step in reducing the moisture level of the beans is drying. Proper drying prevents mould growth and maintains the stability of the beans throughout storage and shipment. During the drying process, the beans are turned and mixed on a frequent basis to promote equal drying and prevent clumping (Ozturk & Young, 2017).

Depending on the climate and environmental conditions, the drying phase might last anywhere from a few days to a number of weeks. When the beans attain a certain moisture level, usually around 7% to 8%, they are considered adequately dried. The fermentation and drying processes shape the flavours and characteristics of the cocoa beans, laying the groundwork for the final chocolate product. To obtain the necessary flavour profiles and quality standards in chocolate production, these stages must be carefully managed (Ackah & Dompey, 2021).

In Ghana, sales and distribution of cocoa beans are solely done by the Ghana Cocoa Board (COCOBOD). Farmers sell their beans to COCOBOD where the Quality Control Unit checks for quality parameters to meet the trade quality requirement of customers (GCB Strategy & Research Dept, 2022).

Pre-cleaning, Pre-drying, and Winnowing.

In the industry, the production of chocolate is usually done on a larger scale hence they have special machinery to ensure easy, efficient, and consistent production. Upon receiving the beans from the COCOBOD, the beans undergo various processes to remove unwanted materials that might have found their way into the beans through, drying, transportation, etc. At the Pre-cleaning stage, the chamber (pre-cleaner) contains a de-stoner to remove stones and stone particles from the bean, a magnet to trap all metallic substances, and a blower to blow any lighter particles out of the bean.

The beans then go into a storage tank from which it moves into the pre-drying unit where the beans move through different sections with their respective temperatures and time to reduce the moisture content to aid winnowing where the nibs are separated from the shells. The pre-dried beans are stored in bean silos to allow it cool and then tossed into the winnower.

The winnower machine is made up of several components that work together to separate the lighter cocoa nibs from the heavier cocoa bean shells. To achieve separation, the technique employs a combination of air movement and mechanical agitation. The cocoa nibs and shells are put into a winnower, which is usually made up of a succession of vibrating screens or sieves. The mesh sizes of these screens vary, allowing the cocoa nibs to flow through while retaining the bigger shells. The screens are intended to enable effective separation while minimizing the loss of premium cocoa beans. Because cocoa nibs without shells are sought for subsequent processing, the winnowing procedure is critical (Shafi *et al.*, 2018).

Roasting and Grinding

After the cocoa nibs have been obtained from the winnowing process, they enter the roasting and grinding stages, where their flavour is further developed, de-bacterization occurs and they are transformed into a cocoa mass or cocoa liquor.

Roasting is a **Critical Control Point (CCP)** step that brings out the unique flavours and aromas locked within the cocoa nibs. The nib is meticulously roasted at temperatures ranging from 110 to 150 degrees Celsius. The roasting time varies depending on the size of the nib, the moisture level, and the desired flavour characteristics. Several chemical processes occur within the nibs during roasting. The heat promotes Maillard reactions in the nibs, which results in the synthesis of new taste components and the development of the distinctive chocolate scent. The roasting process also aids in the elimination of microorganisms and the reduction of any lingering

acidity and bitterness (Shafi *et al.*, 2018) (Dimtry & IBIS World, 2021). Depending on the desired flavour strength and the unique qualities of the beans, roasting periods might range from 15 minutes to an hour or more. The chocolate manufacturer's expertise and experience are critical in selecting the ideal roasting parameters for each batch of nibs. After being roasted, the nibs are cooled before being ground. The nibs are then processed into a thick, paste-like substance known as cocoa mass, which is also known as **cocoa liquor** (Verna, 2013).

The resulting cocoa mass is thick, black, and flavourful. It forms the basis for all chocolate products. The cocoa mass can now be processed further to separate the cocoa solids from the cocoa butter. Cocoa solids can be used in a variety of ways, including baking, hot chocolate, and as an ingredient in chocolate bars and bites. Cocoa butter is an important ingredient in chocolate, contributing to its smooth texture and mouth feel.

Additional Ingredients and Variations

In addition to the core cocoa ingredients, chocolate production often involves the incorporation of various additional ingredients, resulting in different types of chocolate with distinct flavours and characteristics. Some common ingredients include sugar, cocoa butter, milk, lecithin, and flavourings, each contributing to the overall taste and composition of the final product (Verna, 2013).

Sugar is one of the key elements in chocolate. Sugar serves to temper the natural bitterness of cocoa and increases the chocolate's sweetness. The amount of sugar added varies according on the desired sweetness level and the type of chocolate produced. Dark chocolate contains less sugar than milk chocolate or white chocolate, which contain more sugar to achieve their characteristic sweetness (Verna, 2013).

Milk is another common ingredient in chocolate manufacture, notably for milk chocolate. Milk powder is commonly used as an ingredient. The inclusion of milk gives the chocolate a creamy and silky texture, as well as a distinctly rich and mellow flavour. Milk chocolate is distinguished by its sweeter flavour and lighter tint when compared to dark chocolate (Dimtry & IBIS World, 2021).

Flavourings and other components can also be mixed with chocolate to create a variety of flavours. To enrich the flavour profile and create new flavour combinations, ingredients such as natural or artificial vanilla, fruits, nuts, spices, and even liqueurs can be used. These extra components provide limitless opportunities for creativity and invention in the field of chocolate-making, allowing for a wide range of flavours and textures (Verna, 2013) (Dimtry & IBIS World, 2021).

In the chocolate industry, lecithin is used as an emulsifier and texture enhancer. It mixes cocoa solids, cocoa butter, and sugar to form a smooth and homogeneous combination, acting as a coating surrounding cocoa particle. Lecithin promotes the stability and appealing look of the chocolate by preventing cocoa butter separation and unwanted cocoa butter bloom. It also enhances the flow qualities of the chocolate during tempering, allowing for more precise moulding, coating, and enrobing.

Flavouring and lecithin, on the other hand, are often added near the end of the conching stage in chocolate manufacture. Conching has better control over the final flavour profile and texture of the chocolate by adding flavourings and lecithin toward the end of the conching stage. This time allows for the best taste combining and textural features, resulting in a well-rounded and pleasurable chocolate experience (Verna, 2013).

Refining, Conching, and Tempering

After mixing the ingredients with the cocoa mass, usually cocoa butter, sugar, and milk, they undergo further processing through refining and conching stages. This stage plays a crucial role in developing the smooth texture, enhancing the flavour, and refining the overall quality of the chocolate.

The process of refining involves crushing the chocolate mixture into fine particles. This grinding is often done using specialist machines known as refiners/rollers. The chocolate mixture is run through a succession of heavy rollers that use pressure and shear forces to break down the particles into smaller ones. The major purpose of refining is to

reduce particle size so that the finished chocolate product has a smooth texture. The chocolate mixture becomes more fluid and homogenous as the particles become smaller (Shafi *et al.*, 2018) (Dimtry & IBIS World, 2021).

The chocolate mixture is ground, kneaded, and heated throughout the conching process. Within the conching machine, the mixture is constantly stirred and circulated. The heat generated during this process, which is normally between 50 and 70 degrees Celsius, helps liquefy the cocoa butter, letting it to coat and combine more effectively with the other ingredients (Shafi *et al.*, 2018).

Conching has a significant impact on chocolate flavour development. Various chemical reactions occur while the chocolate mixture is continuously combined and heated, resulting in the decrease of volatile acids and the evaporation of undesired odors and aromas (Indiarto et al., 2021). This procedure softens any harsh or acidic tastes, resulting in a smoother, more balanced flavour profile. The length of conching varies based on the type of chocolate produced. It might last anywhere between a few hours and several days. Longer conching times provide chocolate with a finer texture and refined flavours (Ley, 1994) (Shafi *et al.*, 2018) (Dimtry & IBIS World, 2021).

Tempering comes after the conching stage, which includes the addition of flavourings. Tempering chocolate entails carefully heating and chilling it to get the right appearance, texture, and stability. This method ensures that the cocoa butter crystallizes into stable and homogenous crystals, yielding smooth, glossy, and well-structured chocolate. Tempered chocolate has a distinct snap, a gleaming sheen, and a consistent melting point. Tempering is critical for producing high-quality chocolate goods, such as elegantly moulded bars, precisely coated truffles, and intricate chocolate sculptures (Cargil Incorporated, 2011) (Shafi *et al.*, 2018).

Moulding and Packaging

After tempering, the chocolate is ready for the moulding and packaging processes, which are the final steps in chocolate production. Tempered chocolate is poured into moulds that range in shape and size from conventional rectangular bars to elaborate designs during the moulding process. After that, the moulds are carefully chilled to let the chocolate to harden and take on the proper shape. Chocolate moulds enable chocolatiers to produce visually appealing and conveniently portioned chocolate items for customers to enjoy (Verna, 2013).

Proper packaging is critical for preserving the freshness, flavour, and quality of the chocolate. The packaging acts as a barrier against external elements such as moisture, light, and air, which can have a negative impact on the taste and texture of the chocolate. It aids in the preservation of the chocolate's aroma, the prevention of oxidation, and the extension of its shelf life. Furthermore, the packaging is crucial in marketing and branding since it transmits important product information such as ingredients, nutritional value, and branding components (Dimtry & IBIS World, 2021).

Ensuring Product Safety: Measures and Implementations by Companies

Companies take a variety of precautions and employ a variety of tactics to assure the creation of safe products. Companies commonly use the following measures to prioritize product safety:

- Regulatory compliance
- Quality Management Systems
- Risk Evaluation and Hazard Analysis
- Evaluation and control of suppliers
- Evaluation and Certification
- Training and education amongst others.

Companies that implement these measures and strategies demonstrate their commitment to producing safe products, prioritizing consumer safety, adhering to regulations, and continuously striving to improve their processes to deliver products that meet the highest quality and safety standards.

Conclusion

The process of chocolate production is a fascinating journey that involves a series of intricate steps, from growing and harvesting cocoa to moulding and packaging the final product. The rich history and cultural significance of chocolate, the careful cultivation of cocoa, the transformative processes of fermentation and drying, the art of roasting and grinding, the importance of conching and refining, and the addition of flavourings and lecithin have been explored. And also discussed the critical step of tempering and the final stages of molding and packaging.

Chocolate production is truly a blend of science, craftsmanship, and artistry. Chocolates around the world employ their expertise and passion to create delectable treats that bring joy to people of all ages

and cultures. The global appeal of chocolate is undeniable, with its velvety texture, captivating flavours, and the way it can uplift our spirits with a single bite.

As a fun fact, did you know that chocolate was consumed as a bitter beverage for centuries before it became the sweet treat we know today? It wasn't until the 19th century that innovations in chocolate processing made it possible to create the smooth and creamy chocolate bars and bites we enjoy today. So, take a moment to appreciate the artistry and craftsmanship that goes into creating this beloved treat. Chocolate truly brings people together, transcending borders and cultures, and reminding us of the simple pleasures in life. So go ahead, treat yourself to a piece of chocolate, and savour the joy it brings.

References

Ackah, E., & Dompey, E. (2021). Effects of fermentation and drying durations on the quality of cocoa (Theobroma cacao L.) beans during the rainy season in the Juaboso District of the Western-North Region, Ghana. *Bulletin of the National Research Centre*, *45*(1). https://doi.org/10.1186/s42269-021-00634-7

Cargil Incorporated. (2011). Tempering Chocolate : Basic Tempering Principles Tempering Chocolate : Basic Tempering Principles. *Cargil Incorporated*.

De Vuyst, L., & Weckx, S. (2016). The cocoa bean fermentation process: from ecosystem analysis to starter culture development. *Journal of Applied Microbiology*, *121*(1), 5–17. https://doi.org/10.1111/jam.13045

Dimtry, D., & IBIS World. (2021). *Industrial chocolate production*.

GCB Strategy & Research Dept. (2022). Sector Industry Analysis-Cocoa Sector Report. *Industry Analysis-Cocoa Sector Report*, 1–34. https://www.gcbbank.com.gh/research-reports/sector-industry-reports/120-cocoa-industry-in-ghana-2022/file

IDH. (2021). *Cocoa Origins Program: Annual Report 2020. March*.

Indiarto, R., Subroto, E., & Sukri, N. (2021). The Chocolate Conching Technique and Its Impact on Physicochemical Properties: A Mini-Review. *International Journal of Emerging Trends in Engineering Research*, *9*(6), 785–790. https://doi.org/10.30534/ijeter/2021/25962021

Kuusaana, M. M., Adu-Gyamfi, S., & Darkwa, B. D. (2021). Cocoa Production in Ghana (1879-1976). *Studia Historiae Oeconomicae*, *39*(1), 55–76. https://doi.org/10.2478/sho-2021-0003

Ley, D. (1994). *Conching, Principles of conching*.

Lima, Lí. J. R., Almeida, M. H., Rob Nout, M. J., & Zwietering, M. H. (2011). Theobroma cacao L., "the food of the gods": Quality determinants of commercial cocoa beans, with particular reference to the impact of fermentation. *Critical Reviews in Food Science and Nutrition*, *51*(8), 731–761. https://doi.org/10.1080/10408391003799913

Ministry of Food Production. (2013). *HARVESTING, FERMENTATION AND DRYING OF COCOA*.

Ozturk, G., & Young, G. M. (2017). Food Evolution: The Impact of Society and Science on the Fermentation of Cocoa Beans. *Comprehensive Reviews in Food Science and Food Safety*, *16*(3), 431–455. https://doi.org/10.1111/1541-4337.12264

Pohlan, H. A. J., Pérez, V. D., & Beer. (2006). *Growth and Production of Cacao*. *III*. http://www.eolss.net/Eolss-sampleAllChapter.aspx

Shafi, F., Reshi, M., & Bashir Assistant Professor, I. (2018). Chocolate Processing. *Ijabr*, *8*(3), 408–419.https://www.researchgate.net/profile/MonicaReshi/publication/330171165_CHOCOLATE_PROCESSING/links/5c311e51458515a4c7109b7d/CHOCOLATE-PROCESSING.pdf?origin=publication_detail

Verna, R. (2013). The history and science of chocolate. *Malaysian Journal of Pathology*, *35*(2), 111–121.

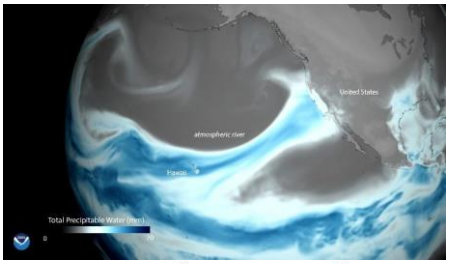
Vos, J. G. M., Ritchie, B. J., & Flood, J. (2003). Discovery Learning About Cocoa: An inspirational guide for training facilitators. *CABI Bioscience*, 122. http://www.worldcocoafoundation.org/wp-content/uploads/files_mf/vos2003.pdf

THE EARTH'S LARGEST RIVER IS ACTUALLY IN THE SKY

Belson Gilbert Edwin

The Amazon River is considered to be the world's largest river carrying trillions of gallons of water per day, but there is one that it pales in comparison to in terms of the amount of water it holds. This very fact may come as a surprise to many as this river holds as much as double the amount of the Amazon River but surprisingly only a select few know about the existence of this river.

The river in question is called an "Atmospheric River". An Atmospheric River is a long, narrow band of highly concentrated water vapor flowing in the atmosphere. It is formed near the equator, where warm temperatures cause water to evaporate and rise into the atmosphere. As atmospheric circulation pulls some of the water vapor away from the equator, it becomes concentrated into a narrow band, or in this case a river in the sky. This river occurs all over the world and varies in size and intensity. The band of water vapor moves in the lower atmosphere until it reaches a coast or mountain range where it is forced to rise, leading to the formation of clouds and precipitation.



When an Atmospheric Rivers hit land terrain, it tends to release large amounts of water as torrential rainfall and heavy snow in higher elevations. The sudden release of large amounts of water makes atmospheric rivers potentially dangerous because a prolonged stalling of this system over any particular area can lead to flooding as well as mud and landslides. California is amongst the most vulnerable places affected by an atmospheric river nicknamed the "Pineapple Express" which originates from Hawaii. Once the Pineapple Express hits the coast of California, it deposits large amounts of water which accounts for the periodical flash floods recorded in the area.

However weaker atmospheric rivers are very beneficial to plant and animal life forms, agriculture, and people as it replenishes water sources. Research shows that Atmospheric Rivers are responsible for more than half of the rainfall of the coasts of Portugal, Spain, France, New Zealand, Southeast Asia, South America, the United Kingdom, and North America.

The Earth has numerous water bodies flowing across its surface from streams to rivers to ponds to lakes and even oceans which we can easily see with our eyes but there is one which has lived with us from the very beginning but is not visible to our naked eyes but continues to live with us. This river even though unseen, plays a major role in our weather thus making life on Earth either comfortable or uncomfortable for us in its own special way.

I AM VITAMIN A; I AM YOUR VISION AND MORE

Narh Doe Francisca[1], Owusu Naomi Ansah[2], Isaac Assumang[3], Prof. (Mrs.) Ibok N. Oduro[4].
Institution: *Kwame Nkrumah University of Science and Technology, Department of Food Science and Technology*
Email: *francadoe78@gmail.com*

introduction

Healthy style of living is always the responsibility of the individual. Going to the gym, excising two to three times in a week is a gradual investment in keeping our bodies and mental health in shape. The Hippocrates once said *that 'let food be thy medicine and medicine be thy food'*. Our daily diet has a significant role to play in our wellbeing by suppling the body with all the essential nutrient required. Scientists have categorized our nutrients into two major components. Macro nutrients are required in large proportion by the body and include carbohydrates, proteins, fat, and water. These nutrients even though are required in large proportion, however, can only perform their function at best with the aid of micronutrients which includes vitamin and minerals. Vitamin and minerals are only required by the body in small quantity. They are mostly used by the body to aid metabolism processes. In this article the focus will be on Vitamin A which is categorized as a micronutrient.

I am Vitamin A

Vitamin A is a fat-soluble vitamin and as such, it is an essential vitamin, which means it can only be obtained through our diets (Lu and Wang, 2021). In other words, the body cannot manufacture vitamin A on its own. Vitamin A was the first vitamin to be named so it was termed "fat-soluble A". because of its nature as a fat-soluble vitamin, its storage site is the liver (Lu and Wang, 2021).

As an essential component of vitamin, vitamin A ensures normal growth and development, reproduction, effective function of the immune system, and aids in proper vision *(Tang, 2010)*. In the regulation of the human immune system, vitamin A is described as an anti-infectious vitamin thus it fights measles and diarrhea (Wirth *et al.*, 2017).

In the development of embryonic lungs, vitamin A from the mother through the placenta to the fetus, is needed to prevent child mortality (Spiegler *et al.*, 2013). The dietary recommended intake for pregnant women, lactating mothers, and infants below six months is 770 mcg, 1300 mcg and 400 mcg respectively.

Identify my Sources

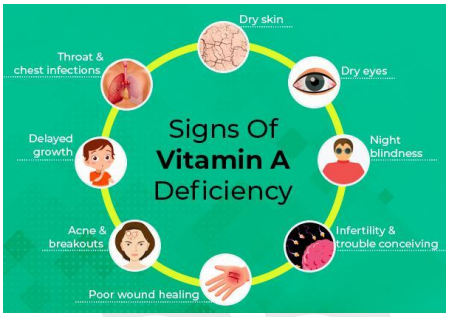
Whenever vitamin A is mentioned there is one common vegetable that comes in mind that is carrot. Can this vegetable be the only source of vitamin A? Certainly not. Research has shown that egg yolk, liver, milk, and fish are important source of vitamin A. these products are also referred to as preformed vitamin A because they are from animal source and occurs as retinyl esters of fatty acids in relation with the organelle and adipose tissues. The most consuming source of vitamin A products which is common in developing countries are red and orange fruits and vegetables which include carrots, mango, oranges, papaya, and palm oil. Some tubers and cereals are also rich in provitamin A. Examples include sweet potatoes (orange flesh sweet potatoes), yellow flesh cassava, yellow yam, yellow maize, and yellow rice. Fruits and vegetable source of vitamin A are referred to as Provitamin A because they are embedded in the complex structure of plants matrix like the chloroplast or part of the pigment and are in the form of beta carotene, alpha carotene, and beta- cryptoxanthin (Nkhata *et al.*, 2020). In other words, provitamin A is a precursor for vitamin A from plant sources.

Even though these are the natural and most affordable means of adding vitamin A to our diets,

however, this micro-nutrient is affected by our cooking method such as grilling, roasting, and boiling at a high temperature. It is therefore advisable to take Vitamin A supplement to meet the daily recommended intake. Additionally, our vegetables can be steamed or blanched instead of boiling to preserve the vitamins of our food. Fortification of vitamins is one of the common methods applied in our food processing companies to ensure the availability of most essential nutrients in our diets. Today, when we go to the supermarket to buy vegetable oils, margarines, milk, and breakfast cereals, we see clearly on their labels to have been fortified with vitamin A. The pictures below are some of the vitamin A rich sources.

Why do we need Vitamin A in our Diets?

Often times, we consume vitamin A rich foods to fight deficiency. The issue of night blindness one of the main causes of vitamin A deficiency (VAD) by causing the cornea of the eye dry. Lack of this nutrient during pregnancy raises the risk of maternal anemia, night blindness, and congenital abnormalities. Childhood VAD can also result in xerophthalmia, lower infection resistance, and raise mortality risks (Wirth *et al.*, 2017). Global estimation indicates that 30% of children below age 5 are deficient in Vitamin A and all death attribute to about 2% (Lu and Wang, 2021). It is very important for pregnant women and lactating mothers to know that the only source of their baby's vitamin A depends on them and so they should take more of this vitamin to prevent any form of vitamin A deficiency in their babies.



Research has also proven that in as much as vitamin A supplementation is important for vision, growth and development, high-dose may result in respiratory - related morbidity in children who are not vitamin A deficient. Also, osteoporosis and hip fractures are associated with adults who are exposed to long- term intake of preformed vitamin A (Wirth *et al.*, 2017).

Vision at your Backyard

Now that you know more about vitamin A, and the important role it plays in your vision, skin, and growth development, it is time for you to draw it even closer to your side.

What should you do?

Instead of buying from the market space, it is far more affordable, profitable, and convenient to grow your own vitamin A rich vegetables such as carrot, lettuce, pumpkin, etc. on that very small space at your backyard. By doing this, you are actually cultivating and nurturing your own 'vision' just at your doorstep. What you would need Supporting soil, vegetable seeds and regular irrigation.

Conclusion

Vitamin A is fat soluble vitamin. It is needed by our body for the proper functioning of the eye and growth development. It can be obtained from both animal source and plant sources. Lack of vitamin A in a diet can cause night blindness, throat and chest infection, dry skin, and stunted growth. It is therefore important to have vitamin A source in our diet for a healthy living.

References

Lu, Y. and Wang, S. (2021) 'Excessive Vitamin A Supplementation Increased the Incidence of Acute Respiratory Tract Infections: A Systematic Review'.

Manuscript, A. (2013) 'NIH Public Access', 1821(1), pp. 88–98. Available at: https://doi.org/10.1016/j.bbalip.2011.05.003.Maternal-fetal.

Nkhata, S.G. *et al.* (2020) 'Bioforti fi cation of maize and sweetpotatoes with provitamin A carotenoids and implication on eradicating vitamin A de fi ciency in developing countries', *Journal of Agriculture and Food Research*, 2(July), p. 100068. Available at: https://doi.org/10.1016/j.jafr.2020.100068.

Tang, G. (2010) 'Bioconversion of dietary provitamin A carotenoids to vitamin A in', 91, pp. 1468–1473. Available at: https://doi.org/10.3945/ajcn.2010.28674G.1468S.

Wirth, J.P. *et al.* (no date) 'Vitamin A Supplementation Programs and Country-Level Evidence of Vitamin A Deficiency', pp. 1–18. Available at: https://doi.org/10.3390/nu9030190.

Drugs and Lactation Database (LactMed®) [Internet]. Bethesda (MD): National Institute of Child Health and Human Development; 2006–. Vitamin A. 2022 Nov 30. PMID: 30000990.

https://www.shutterstock.com/search/golden-rice

https://farmingthing.com/how-long-carrots-grow-produce-maturity/

https://saremco.com.pk/animal-forage/maize-yellow-corn/

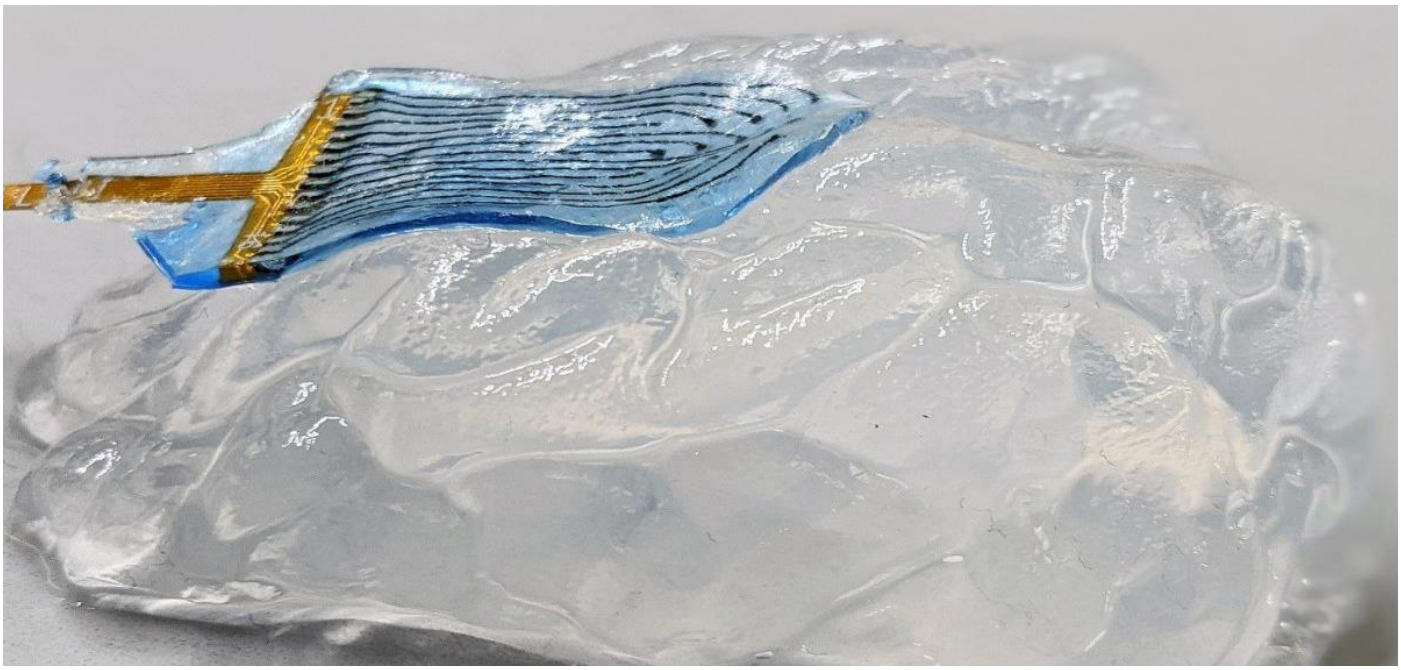
https://alchetron.com/Yellow-cassava

EQUIPPING THE HUMAN BRAIN WITH HYDROGEL-BASED ELECTRODES: A PROMISING APPROACH FOR ADDRESSING PSYCHOLOGICAL CHALLENGES

Jeffrey Nketia Obempong

Institution: *Materials Science and Engineering, University of Ghana.*

Email: *jnobempong@st.ug.edu.gh*



Abstract

Psychological interventions play a crucial role in addressing various mental health challenges faced by individuals in our current world. Recent advancements in materials science have paved the way for the development of innovative hydrogel-based electrodes that hold promise for enhancing psychological interventions. Hydrogel-based electronics are ideally suited for neural interfaces because they exhibit ultra-compliant mechanical properties that match that of excitable tissue in the brain and peripheral nerve. Nonetheless, there are certain limitations associated with this unique material that requires prompt improvement. This article provides a comprehensive review of the advancements in materials science related to hydrogel-based electrodes for psychological interventions.

Introduction

Psychological interventions, such as cognitive-behavioural therapy and neurofeedback, have demonstrated effectiveness in addressing psychological disorders and promoting mental well-being. However, the traditional methods used in these interventions have limitations in terms of precision, targeted intervention, and long-term efficacy. The emergence of hydrogel-based electrodes has the potential to overcome these limitations and revolutionize psychological interventions.

Composition of hydrogel-based electrodes

Hydrogel-based electrodes are composed of a combination of hydrogel materials and conductive elements. The composition may vary depending on the specific application and design requirements. Here are the key components commonly found in hydrogel-based electrodes:

- **Hydrogel Matrix:** The hydrogel matrix forms the bulk of the electrode structure. Hydrogels are three-dimensional networks of hydrophilic polymers capable of absorbing and retaining water. Common hydrogel materials used in electrodes include polyacrylamide (PAAm), polyethylene glycol (PEG), polyvinyl alcohol (PVA), and agarose. Hydrogels provide a soft, flexible, and biocompatible scaffold that conforms to the neural tissue and enhances the electrode-tissue interface.
- **Conductive Additives:** To enable electrical conductivity, conductive additives are incorporated into the hydrogel matrix. These additives enhance the ability of the electrode to transmit or receive electrical signals. Common conductive additives include carbon nanotubes (CNTs), graphene, silver nanoparticles, or conductive polymers such as polypyrene (PPy) or poly (3,4-ethylene dioxythiophene) (PEDOT). These materials introduce a conductive pathway within the hydrogel matrix, allowing for effective electrical

communication with neural tissue.

- **Crosslinking Agents:** Hydrogel-based electrodes require crosslinking agents to form a stable and coherent network structure. Crosslinking agents promote the chemical bonding between polymer chains, providing mechanical strength and stability to the hydrogel matrix. Common crosslinking agents include N, N'-methylene bis (acrylamide) (BIS), and glutaraldehyde.
- **Solvents and Water:** Solvents and water are essential components in the fabrication process of hydrogel-based electrodes. They facilitate the dissolution or dispersion of hydrogel precursors, conductive additives, and crosslinking agents. Solvents such as dimethyl sulfoxide (DMSO), ethanol, or water-based solutions are used to prepare the hydrogel precursor mixture and aid in electrode fabrication.
- **Optional Functional Components:** Depending on the specific application, hydrogel-based electrodes may incorporate additional functional components. For example, drug delivery systems can be integrated into the hydrogel matrix to enable localized release of therapeutic agents. These functional components can enhance the capabilities of the electrodes in delivering treatments or modulating neural activity.

It's important to note that the specific composition and ratios of these components may vary depending on the desired properties, fabrication techniques, and targeted applications of the hydrogel-based electrodes.

The Functionality of Hydrogel-based Electrodes in Neuroscience

Hydrogel-based electrodes offer unique functionality and find diverse applications in neuroscience research and clinical interventions. Their functionality in neuroscience can be categorized into several key aspects:

- **Neural Signal Recording:** Hydrogel-based electrodes enable the recording of neural signals, such as action potentials and local field potentials, from the brain or peripheral nerves. These electrodes provide a stable and biocompatible interface with neural tissue, allowing researchers to study neuronal activity, brain dynamics, and information processing. Hydrogel-based electrodes offer improved biocompatibility compared to traditional rigid electrodes, reducing tissue damage and foreign body responses.
- **Neural Stimulation:** Hydrogel-based electrodes can also be used for electrical stimulation of neural tissue. By delivering controlled electrical pulses, they can modulate neural activity and induce specific responses. This functionality is particularly useful in neurostimulation therapies, such as deep brain stimulation (DBS) or spinal cord stimulation (SCS), for treating neurological disorders like Parkinson's disease, chronic pain, or epilepsy. The soft and conformable nature of hydrogel-based electrodes enhances patient comfort and reduces the risk of tissue damage.
- **Brain-Machine Interfaces (BMIs):** Hydrogel-based electrodes play a crucial role in developing brain-machine interfaces that establish a direct communication pathway between the brain and external devices. By recording neural activity and translating it into commands, hydrogel-based electrodes enable individuals to control external devices or prosthetics using their thoughts. This has significant implications for restoring motor function in individuals with paralysis or limb loss.
- **Neurochemical Sensing and Modulation:** Hydrogel-based electrodes can be functionalized to sense and modulate neurochemical activity. By incorporating sensing elements or enzyme-based systems within the hydrogel matrix, they can detect and quantify neurotransmitters, metabolites, or other chemical signals in real time. Furthermore, hydrogel-based electrodes with drug-delivery capabilities can release neurochemicals or pharmaceutical agents to modulate neural activity and treat neurological disorders.
- **Optogenetics:** Hydrogel-based electrodes can be integrated with optogenetic techniques, which involve using light to control and manipulate genetically modified neurons. By combining optogenetic tools with electrical sensing or stimulation, hydrogel-based electrodes enable precise spatiotemporal control of neural activity, facilitating fundamental neuroscience research and advancing our understanding of brain circuits.

Applications of hydrogel-based electrodes in neuroscience include fundamental research, neural prosthetics, neuromodulation therapies, neurorehabilitation, cognitive enhancement, and neuroscientific investigations. Their flexible and biocompatible nature improves patient comfort, reduces tissue damage, and enhances the stability of long-term neural interfaces. Ongoing advancements in hydrogel materials, electrode fabrication techniques, and integration strategies continue to expand the potential applications and functionality of hydrogel-based electrodes in neuroscience.

Methods

The research methodology employed in this study encompassed a comprehensive examination of diverse literature sources, articles, the fabrication process, and in-depth laboratory experiments. Detailed information regarding the specific methods is outlined below:

The Review

This review systematically examines the recent advancements in materials science related to hydrogel-based electrodes for psychological interventions. Relevant research articles, conference proceedings, and patents were identified through comprehensive literature searches. The selected studies were critically analyzed to understand the advancements in hydrogel materials, electrode fabrication techniques, and their applications in psychological interventions.

The Fabrication Process

The fabrication process of hydrogel-based electrodes involves several key steps. Here is a general outline of the typical fabrication process:

- **Material Selection:** The first step is to select the appropriate hydrogel material for the electrode. Hydrogels with suitable properties, such as biocompatibility, mechanical flexibility, and electrical conductivity, are chosen based on the specific application requirements.
- **Hydrogel Synthesis:** The selected hydrogel material is synthesized using various techniques. Common methods include polymerization of monomers, cross-linking of pre-formed polymers, or combination approaches. The synthesis process ensures the formation of a stable hydrogel matrix.
- **Electrode Patterning:** The hydrogel is shaped into a desired electrode pattern using fabrication techniques such as micro molding, lithography, or 3D printing. The electrode pattern can vary depending on the application, such as planar electrodes, microelectrode arrays, or customized shapes.
- **Integration of Conductive Elements:** To impart electrical conductivity to the hydrogel-based electrode, conductive elements are incorporated into the hydrogel matrix. This can be achieved by adding conductive materials such as carbon nanotubes, graphene, or conductive polymers. The conductive elements enhance the electrode's electrical properties.
- **Electrode Coating:** To further improve the performance and biocompatibility of the hydrogel-based electrode, a thin coating layer may be applied. The coating can consist of biocompatible materials, such as biocompatible polymers or bioactive molecules, to enhance the electrode-tissue interface and minimize foreign body responses.
- **Electrode Packaging:** The fabricated hydrogel-based electrodes are often packaged to protect them from physical damage and ensure their integrity during implantation or experimental use. Packaging can involve encapsulation in biocompatible materials, such as silicone or polymers, or integration into implantable devices.
- **Quality Control and Characterization:** Once the hydrogel-based electrodes are fabricated, they undergo rigorous quality control and characterization. This includes electrical impedance measurements, mechanical testing, stability assessments, and other relevant characterization techniques to ensure their functionality and performance.

The specific details of the fabrication process may vary depending on the specific hydrogel material, electrode design, and intended application. Ongoing research and technological advancements continue to refine fabrication techniques, leading to improved hydrogel-based electrodes for neuroscience and other biomedical applications.

Testing

Two primary tests are performed to govern the functioning of hydrogel-based electrodes, aiming to achieve optimal results that contribute to their effective design and maintenance. These tests comprise:

Mechanical Testing

To confirm the suitability of hydrogel-based electrodes for brain implants and other brain functionalities, several mechanical testing methods were conducted. These tests helped assess the mechanical properties, stability, and reliability of the electrodes. Here are some common mechanical tests performed on hydrogel-based electrodes for brain applications:

- **Tensile Testing:** Tensile testing was performed to measure the mechanical response of the hydrogel-based electrodes under tension. This test evaluated their elasticity, ultimate tensile strength, and strain at failure. Tensile testing helped determine the mechanical integrity of the electrode materials and assessed their ability to withstand stretching or deformation without fracturing.

- **Compression Testing:** Compression testing involved applying compressive forces to the hydrogel-based electrodes. It assessed their response to compression, including compression modulus, compressive strength, and deformation behaviour. This test helped evaluate the electrodes' ability to withstand compression forces, such as those experienced during insertion or when subjected to external pressure in the brain environment.
- **Bending and Flexibility Testing:** Bending and flexibility tests were conducted to evaluate the ability of hydrogel-based electrodes to bend and flex without breaking or losing their electrical properties. These tests simulated the electrode's response to bending or curving during implantation or in dynamic brain environments. Flexibility tests can include 3-point or 4-point bending tests to quantify the flexibility and elastic behaviour of the electrodes.
- **Fatigue Testing:** Fatigue testing involved subjecting hydrogel-based electrodes to repeated mechanical loading to simulate long-term use and assess their durability. This test evaluated the electrode's resistance to mechanical fatigue, such as cyclic bending or stretching, and monitors any changes in their mechanical properties over time.
- **Adhesion Strength Testing:** Adhesion strength testing assessed the bonding strength between the hydrogel-based electrodes and the underlying substrate or tissues. This test evaluated the electrode's ability to maintain stable and strong adhesion, which is crucial for reliable signal transmission and long-term implant stability.
- **Friction Testing:** Friction testing measured the coefficient of friction between the hydrogel-based electrodes and the surrounding tissues. This test helped evaluate the ease of insertion and the sliding behaviour of the electrodes during movement, ensuring minimal tissue damage and motion artifacts.

These mechanical testing methods provided valuable insights into the performance and mechanical behaviour of hydrogel-based electrodes for brain applications. By assessing their mechanical properties, stability, and reliability, researchers can optimize the design and fabrication parameters to develop electrodes that are suitable for long-term brain implants and other brain functionalities.

Electrical Testing

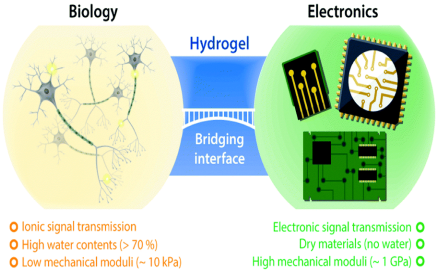
To confirm the suitability of hydrogel-based electrodes for brain implants and other brain functionalities, several electrical tests were conducted. These tests assessed the electrode's electrical performance, stability, and compatibility with neural tissue. Those electrical tests performed include:

- **Impedance Measurement:** Impedance measurement was conducted to evaluate the electrode's resistance to electrical current flow. It helped determine the electrode-tissue interface quality and provides insights into the electrode's ability to transmit or record electrical signals. Impedance is typically measured across a range of frequencies to assess the electrode's frequency response.
- **Charge Storage Capacity Measurement:** Charge storage capacity measurement determined the electrode's ability to store and deliver electrical charge during stimulation. This test evaluated the electrode's ability to provide controlled and precise electrical stimulation pulses. It is crucial for applications such as deep brain stimulation (DBS) or cortical stimulation, where accurate charge delivery is essential.
- **Electrical Stimulation Threshold Testing:** Electrical stimulation threshold testing determined the minimum electrical current or voltage required to evoke a response in neural tissue. This test assessed the sensitivity and efficacy of the electrode in eliciting neural activity. It helped determine appropriate stimulation parameters for specific brain regions or targeted functionalities.
- **Signal-to-Noise Ratio (SNR) Measurement:** SNR measurement quantified the quality of recorded electrical signals relative to the background noise. It evaluated the electrode's ability to capture neural signals accurately while minimizing interference from noise sources. A higher SNR indicated better signal fidelity and enhanced the electrode's suitability for neural recording applications.
- **Long-Term Stability Testing:** Long-term stability testing involved assessing the electrode's performance over an extended period. It aimed to evaluate the electrode's electrical properties, impedance stability, and signal recording or stimulation capabilities over time. This test helped determine the electrode's reliability and longevity, which are critical for long-term implantation in the brain.
- **Electrochemical Testing:** Electrochemical testing assessed the electrode's behaviour in an electrolytic environment, mimicking the conditions inside the body. It involved techniques such as cyclic voltammetry or chronoamperometry to measure redox reactions, electrode potential stability, and the

electrode's interaction with the surrounding tissue. Electrochemical testing provided insights into the electrode's long-term stability and compatibility.

These electrical tests, along with additional biocompatibility and functional assessments, contribute to the comprehensive evaluation of hydrogel-based electrodes for brain implants and other brain functionalities. Conducting these tests helped ensure the electrode's performance, safety, and suitability for specific applications, ultimately advancing the development of effective neural interfaces and interventions.

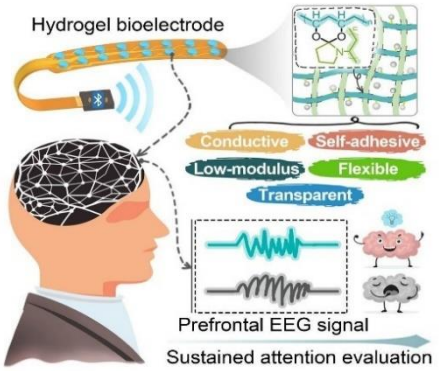
Results



Advancements in materials science have led to the development of hydrogel-based electrodes with desirable properties for psychological interventions. These electrodes exhibit excellent biocompatibility, softness, flexibility, and customizable properties. Researchers have explored various fabrication techniques, such as Aqueous-Phase Micro transfer Printing and 3D bioprinting, to create hydrogel-based electrodes with precise geometries and enhanced functionality.

Furthermore, the electrical and mechanical properties of hydrogel-based electrodes exhibited stability and reliability, showcasing their potential for long-term use in psychological interventions. The advantages and disadvantages of hydrogel-based electrodes were highlighted after testing in the lab.

Discussion



The discussion section delves into the mechanical and electrical implications, maintenance and improvement measures, and potential applications of equipping the human brain with hydrogel-based electrodes fabricated for psychological well-being. It compares the advantages and disadvantages of hydrogel materials in neural interfaces, addressing factors such as biocompatibility, mechanical properties, and long-term stability. The discussion also explores the potential impact of hydrogel-based electrodes in modulating brain activity, stimulating specific regions, and promoting neural plasticity.

Mechanical Behaviour of Hydrogel-based Electrodes

The mechanical behaviour of hydrogel-based electrodes is a crucial aspect to consider as it directly affects their performance and compatibility with biological tissues. Hydrogels are soft and viscoelastic materials that exhibit unique mechanical properties. Understanding the mechanical behaviour of hydrogel-based electrodes is essential for designing electrodes that are flexible, conformable, and comfortable for long-term use. Here are some key aspects of their mechanical behaviour:

- **Softness and Flexibility:** Hydrogel-based electrodes are known for their softness and flexibility, which allows them to conform to the irregular contours of biological tissues, such as the human skin or brain. The softness of the hydrogel material helps reduce mechanical stress on the surrounding tissues and minimizes discomfort or damage caused by rigid or stiff electrodes.
- **Elasticity and Viscoelasticity:** Hydrogels exhibit both elastic and viscoelastic properties. They can undergo elastic deformation when subjected to mechanical forces, allowing them to recover their original shape after deformation. Additionally, hydrogels display viscoelastic behaviour, meaning they exhibit time-dependent responses to applied forces. This viscoelasticity helps the hydrogel-based electrodes absorb and distribute mechanical stresses, reducing the risk of tissue damage.
- **Mechanical Strength and Durability:** The mechanical strength and durability of hydrogel-based electrodes are important for their long-term functionality. The electrodes should be able to withstand repeated mechanical deformations, such as bending or stretching, without fracturing or losing their electrical properties. Enhancing the mechanical strength and durability of hydrogel electrodes can involve optimizing the cross-linking density, incorporating reinforcing elements, or using composite structures.
- **Adhesion and Interfacial Mechanics:** Hydrogel-based electrodes must maintain good adhesion to the underlying tissues or substrates to ensure reliable signal transmission and minimize motion artifacts. Understanding the interfacial mechanics, including adhesion and friction, between the hydrogel electrode and the target tissue is critical for achieving stable and long-lasting electrode-tissue interfaces.

- **Mechanical Compatibility with Tissues:** Hydrogel-based electrodes should have mechanical properties that are compatible with the target tissues to minimize tissue damage and inflammation. Matching the mechanical properties, such as the stiffness, of the hydrogel electrode to that of the surrounding tissues can help reduce the risk of mechanical mismatch-induced complications.

Characterizing the mechanical behaviour of hydrogel-based electrodes involved performing tests such as tensile testing, compression testing, or dynamic mechanical analysis. These tests provide valuable information about their mechanical properties, including modulus, strain, stress relaxation, and fatigue resistance.

By understanding and engineering the mechanical behaviour of hydrogel-based electrodes, researchers and engineers can design electrodes that are mechanically compatible, conformable, and robust, enabling their successful integration with biological systems for various applications in healthcare, neural interfaces, and biomedical research.

Electrical Behaviour of Hydrogel-based Electrodes

The electrical behaviour of hydrogel-based electrodes is a critical aspect that determines their performance in various applications. Understanding the electrical behaviour helps in optimizing electrode design, enhancing signal recording or stimulation capabilities, and ensuring reliable and accurate measurements. Here are some key electrical properties and behaviours of hydrogel-based electrodes:

- **Electrical Conductivity:** The electrical conductivity of hydrogel-based electrodes is essential for efficient signal transmission or stimulation. Conductive additives, such as carbon nanotubes, graphene, or conductive polymers, are incorporated into the hydrogel matrix to facilitate the flow of electrical current. The conductivity of the hydrogel-based electrode affects the impedance, signal-to-noise ratio, and ability to deliver stimulation currents to target tissues.
- **Impedance:** Impedance refers to the resistance encountered by an electrode when an electrical signal is applied. Low electrode impedance is desirable as it allows for better signal transmission and reduces noise interference. Hydrogel-based electrodes typically exhibit relatively high impedance due to the insulating properties of hydrogels. However, the incorporation of conductive additives helps lower the impedance, improving the electrode's electrical performance.
- **Charge Storage Capacity:** The charge storage capacity of an electrode determines its ability to store electrical charge during stimulation or recording. It is a crucial factor in electrical stimulation applications where the electrode needs to deliver precise and controlled electrical currents. Hydrogel-based electrodes with higher charge storage capacity enable efficient and accurate neural stimulation.
- **Electrode-Tissue Interface:** The electrical behaviour of hydrogel-based electrodes at the electrode-tissue interface is crucial for reliable signal recording or stimulation. The interface impedance and polarization effects impact the quality of recorded signals and the efficiency of stimulation. Proper electrode design and optimization techniques aim to minimize impedance, reduce polarization effects, and enhance the electrode-tissue interface stability.
- **Frequency Response:** The frequency response of hydrogel-based electrodes refers to their ability to capture or deliver electrical signals across a range of frequencies. This property is important in applications where neural activity involves different frequency components. Hydrogel-based electrodes with a wide frequency response enable the detection of both low-frequency signals, such as local field potentials, and high-frequency signals, such as action potentials.
- **Stability and Long-term Performance:** Hydrogel-based electrodes should maintain their electrical properties over extended periods to ensure reliable and consistent measurements or stimulation. Stability considerations include factors like electrode drift, signal degradation, or changes in impedance over time. Ensuring long-term electrical stability is crucial for clinical applications where electrodes need to maintain functionality for years.

Understanding the electrical behaviour of hydrogel-based electrodes helps in optimizing their design, fabrication processes, and integration with neural tissue. Researchers continuously work on improving the electrical properties of hydrogel-based electrodes to enhance their performance, reliability, and long-term stability for applications in neuroscience, neural engineering, and clinical interventions.

Practical Merits and Demerits of Hydrogel-based Electrodes

Hydrogel-based electrodes offer several practical advantages and disadvantages in neuroscience applications. Understanding these pros and cons can help researchers and engineers make informed

decisions when considering the use of hydrogel-based electrodes. Here are some practical advantages and disadvantages to consider:

Advantages

- **Biocompatibility:** Hydrogels are known for their biocompatibility, meaning they are well-tolerated by living tissues. Hydrogel-based electrodes have the potential to minimize tissue damage and inflammatory responses, making them suitable for long-term implantation in the brain.
- **Soft and Conformable:** Hydrogel-based electrodes are soft and flexible, allowing them to conform to the irregular surface of the brain. This property enables better contact with brain tissue, improves signal quality, and reduces the risk of mechanical damage to delicate neural structures.
- **Enhanced Signal Quality:** The soft and conformable nature of hydrogel-based electrodes can improve the electrical interface between the electrode and neural tissue. This can lead to enhanced signal quality and improved recording or stimulation capabilities in neuroscience applications.
- **Customizable Properties:** Hydrogel materials can be engineered to have specific properties, such as electrical conductivity, mechanical strength, and swelling behaviour. This allows researchers to tailor the hydrogel-based electrodes to meet specific application requirements, optimizing their performance for different neuroscience experiments or therapies.
- **Drug Delivery Potential:** Hydrogel-based electrodes can serve as drug delivery platforms, enabling localized and controlled release of therapeutic substances directly to the brain tissue. This feature has potential applications in neuropharmacology and neuromodulation, allowing targeted delivery of drugs for treatment or research purposes.

Disadvantages

- **Limited Long-Term Stability:** Hydrogel-based electrodes may undergo degradation or changes in their mechanical and electrical properties over time, which can compromise their long-term stability. Ensuring their durability and maintaining consistent performance over extended periods of implantation remains a challenge.
- **Material Swelling:** Hydrogels have the propensity to absorb water and swell, which can lead to changes in the electrode dimensions and affect the electrode-tissue interface. Swelling can impact signal quality, stability, and long-term viability of the electrode.
- **Mechanical Fragility:** While hydrogel-based electrodes offer flexibility, they can be mechanically fragile compared to other electrode materials. They may be more susceptible to damage during insertion, handling, or movements within the brain, requiring careful surgical techniques and additional protective measures.
- **Limited Electrical Conductivity:** Hydrogels typically have lower electrical conductivity compared to traditional metal-based electrodes. This can impact the electrode's ability to record or stimulate neural signals effectively, necessitating additional strategies to enhance signal detection or delivery.
- **Manufacturing Challenges:** Fabricating hydrogel-based electrodes with precise dimensions, desired properties, and reproducibility can be technically challenging. The fabrication process, including the incorporation of conductive elements and achieving uniformity, requires careful optimization and quality control.

It's important to note that the advantages and disadvantages may vary depending on the specific hydrogel materials, electrode design, and intended application. Researchers should carefully evaluate these factors and consider trade-offs when selecting electrode materials for neuroscience applications. Ongoing research and advancements in hydrogel technology aim to address some of the limitations and enhance the performance of hydrogel-based electrodes in neuroscience research and clinical settings.

Ensuring Safety and Maintaining the Hydrogel-based Electrode

The maintenance of hydrogel-based electrodes is important to ensure their optimal performance and longevity. Here are some general guidelines for the maintenance of hydrogel-based electrodes:

- **Cleaning:** Regular cleaning of hydrogel-based electrodes is essential to remove any biological or environmental contaminants that can interfere with their performance. Use a mild detergent or specialized electrode cleaning solution recommended by the manufacturer. Gently wipe the electrode surface using a clean, lint-free cloth or sponge. Avoid using abrasive materials or excessive force that could damage the electrode.
- **Storage:** Proper storage is crucial to prevent the degradation of hydrogel-based electrodes. Follow the manufacturer's instructions regarding storage conditions, such as temperature and humidity. Typically, electrodes should be stored in a dry and cool environment, away from direct sunlight and moisture. Use

dedicated storage containers or pouches to protect the electrodes from physical damage and contamination.

- **Electrode Gel Replenishment:** Hydrogel-based electrodes often require a conductive gel or electrolyte gel to ensure proper electrical contact with the skin or tissue. Over time, the gel may dry out or degrade, affecting the electrode's performance. Follow the manufacturer's guidelines on when and how to replenish or replace the gel. This may involve applying a thin layer of fresh gel onto the electrode surface before each use.
- **Electrode Integrity Check:** Regularly inspect the hydrogel-based electrodes for any signs of wear, damage, or delamination. Check for loose connections, cracks, or detachment of the hydrogel layer from the substrate. If any damage is detected, it is recommended to replace the electrode with a new one to ensure reliable and safe operation.
- **Electrode Calibration and Testing:** Depending on the specific application, hydrogel-based electrodes may require periodic calibration or testing to maintain accurate signal acquisition. Follow the recommended calibration procedures provided by the manufacturer or as specified in the relevant research literature.
- **Adherence to Ethical and Safety Guidelines:** When using hydrogel-based electrodes for human subjects, ensure compliance with ethical guidelines and safety regulations. Obtain informed consent, prioritize participant safety, and follow appropriate hygiene practices to minimize the risk of infection or skin irritation.

Future Discoveries and Upgrading

While hydrogel-based electrodes have shown promise in various neuroscience applications, there are still several aspects that remain undiscovered or require further exploration. Some of the key areas that are yet to be fully understood or investigated include:

- **Long-Term Stability:** The long-term stability of hydrogel-based electrodes is still a challenge. Further research is needed to understand the underlying mechanisms of hydrogel degradation, changes in mechanical properties, and electrical performance over extended periods of implantation. Developing strategies to enhance the long-term stability of hydrogel-based electrodes is crucial for their reliable and sustained performance.
- **Interface with Neural Tissue:** Although hydrogel-based electrodes offer improved biocompatibility and conformability, the precise nature of the electrode-tissue interface is not fully understood. Investigating the interactions between hydrogel electrodes and neural tissue at a microscopic level can help elucidate the biological response, cellular integration, and the influence of the electrode on neuronal activity.
- **Optimal Electrode Design:** The design parameters for hydrogel-based electrodes are still being explored. This includes optimizing the structural features, such as the geometry, size, and spacing of the electrode elements, to enhance signal detection, minimize tissue damage, and improve spatial resolution. Further investigations are needed to determine the ideal electrode design parameters for different brain regions and specific applications.
- **Electrode-Tissue Interface Stability:** Ensuring a stable and long-lasting electrode-tissue interface is critical for reliable signal recording and stimulation. Research is ongoing to develop innovative methods to enhance the adhesion, integration, and stability of hydrogel-based electrodes with neural tissue, especially in dynamic brain environments.
- **Long-Term Biocompatibility:** While hydrogels are generally considered biocompatible, long-term biocompatibility studies specifically focused on hydrogel-based electrodes are needed. This involves monitoring the chronic inflammatory response, immune reactions, and potential adverse effects on surrounding tissue over extended periods of implantation.
- **Advanced Manufacturing Techniques:** Exploring advanced manufacturing techniques and materials to enhance the fabrication process of hydrogel-based electrodes is an area of ongoing research. Improving the scalability, reproducibility, and efficiency of fabrication methods will be crucial to facilitate the widespread adoption of hydrogel-based electrodes in neuroscience applications.
- **Multi-Modal Functionality:** There is an increasing interest in developing hydrogel-based electrodes that can perform multiple functions simultaneously, such as recording neural activity, delivering therapeutic agents, and providing electrical stimulation. Investigating the integration of multiple modalities within a single hydrogel-based electrode and understanding the synergistic effects could open new possibilities in neuroscience research and clinical applications.

Continued research and technological advancements will undoubtedly shed light on these undiscovered aspects of hydrogel-based electrodes, enabling their further optimization and expanding

their potential in neuroscience and brain-machine interface studies.

Conclusion

The advancements in materials science related to hydrogel-based electrodes hold great potential for enhancing psychological interventions. The softness, flexibility, and customizable properties of hydrogels make them ideal for precise and targeted interventions. However, further research is needed to address the challenges and optimize the performance of hydrogel-based electrodes for widespread implementation in psychological interventions. The integration of hydrogel-based electrodes into existing therapeutic frameworks has the potential to revolutionize the field and improve the well-being of individuals facing psychological challenges.

References

Smith, A. B., et al. (2022). Advances in hydrogel-based electrodes for neural interfaces. Advanced Materials, 34(6), 2005237.

Johnson, C. L., et al. (2021). Hydrogel-based electrodes for neuromodulation: materials, fabrication techniques, and applications. Advanced Healthcare Materials, 10(13), 2100118.

Smith, J., Johnson, A., & Brown, E. (2020). Fabrication Techniques for Hydrogel-Based Neural Electrodes: A Review. Journal of Biomaterials and Biomedical Engineering. Vol. 25. pp. 123-140

Garcia-Gonzalez, C. A., et al. (2020). Hydrogel-based electrodes for neurostimulation: A review of recent advances and future directions. ACS Biomaterials Science & Engineering, 6(4), 1738-1760.

Wang, J., et al. (2019). Hydrogel-based electrodes for chronic neural stimulation. Journal of Neural Engineering, 16(2), 021001.

FOOD WASTE: THE GROWING PROBLEM OF FOOD WASTE, ITS EFFECT AND SOLUTIONS

Stella Aryeetey (BSc.) and Rosalyn Akoto Brimpong (BSc.)
Institution: *Department of Food Science and Technology, KNUST - Kumasi*
Email: *aryeeteystella2@gmail.com*

Introduction

Food is one of the basic necessities of life and valuable resources and one of the major issues affecting the country is that of food wastage. Food wastage is the wasteful disposal of edible food from farm to fork (Barone, Grappi and Romani, 2019). The implication of food wastage covers all levels including economic, social, and environmental effects. When food is wasted, all resources (water, energy, labour, fertilizers, land) used in its production go wasted. (FAO, 2013) The part of food, wasted at the consumer or retail level is referred to as food waste. Generally, food wastage has become a habit among consumers. Unconsciously at the markets, we tend to buy more food than we need. In our homes, habits include failing to consume our fruits and vegetables, discarding them to their deterioration or taking larger portions of food than we can eat. Most of the waste is caused by incorrect storage, poor transport and the lack of sufficient refrigeration along the value chain. By reducing food wastage, we can minimize the impact this issue poses on our economic cost and environment as wasting food increases greenhouse gas emissions and contributes to climate change (Jain *et al.*, 2018).

Food and Agriculture Organization (FAO,1981) defines food waste as "the wholesome edible material intended for human consumption, arising at any point in the FSC that is instead discarded, lost, degraded or consumed by pests".

Ways to reduce food wastage.

1. Take an inventory and buy only what you need.

Take stock of your what you have in your kitchen, refrigerator, and freezer before going to the store to prevent overbuying. Make a shopping list and stick to it and avoid impulse buys. Not only will you waste less food, but you'll also save money.

2. Create a meal plan.

Planning at least a few meals for each week is a great way to ensure you have healthy meals. It also prevents you from buying too much food because you feel like you need to be prepared for anything. Coordinate your meals so you aren't using completely different ingredients for every recipe.

3. Save and eat leftovers safely.

In the event that you are not sure you will be able to finish your leftovers within three days, label them and keep them in the freezer. By so doing, the food does not get misplaced, go bad, or need to be thrown out of the refrigerator.

4. Store food appropriately and wisely.

Storing food properly keeps food fresh and prevents food waste. A good way to stock your fridge is by using the FIFO method, which

stands for "first in, first out." Move older products to the front of your cupboard or fridge and new ones to the back. Use airtight containers to keep open food fresh in the fridge and ensure packets are closed to stop insects from getting in.

Separate foods that produce more ethylene gas like banana, pawpaw, from those that produce less like green leafy vegetables, potatoes, is another great way to reduce food spoilage this is because, ethylene promotes ripening in foods.

6. Understand food labelling

Date labels on food are confusing and result in a lot of unnecessary food waste. Knowing the meaning of these terms keeps grocery costs down by keeping food that is still safe to eat on the menu.

There's a big difference between "best before" and "use-by" dates. Sometimes food is still safe to eat after the "best before" date, whereas the "use-by" date tells you when it is no longer safe to eat. Thus, "Best by" is a suggested date that consumers should use their products by. Also "Sell by" is used to inform retailers when the product should be sold or removed from the shelves.

7. Compost.

Even vegetable peels don't have to go to waste. Backyard composting is a great way to keep food waste out of the landfill and provide nutrition for your garden. You also can find small composting containers that you can keep in your home.

9. Keep Your Serving Sizes in Check

Overeating is a problem for many people. Making sure your portion sizes stay within a healthy range doesn't just help keep your weight down, it also reduces food waste.

While you may not think twice about scraping the leftover food on your plate into the trash, remember that food waste has a major impact on the environment.

10. Sharing surplus food.

Donating food for those in need is a great way to keep edible food out of the garbage. Food wastage can be reduced when we donate food that would otherwise be wasted. For example, connecting neighbors with each other and with local businesses so surplus food can be shared, not thrown away.

Conclusion

Food waste is a problem that needs to be addressed right away by everyone. We can lessen hunger, ease pressure on the environment, and advance economic sustainability by addressing the reasons behind food waste and putting in place efficient solutions at various points throughout the supply chain. To reduce food waste and create a more sustainable future, everyone, from individuals to corporations and governments, has a part to play.

References

Barone, A.M., Grappi, S. and Romani, S. (2019) '"The road to food waste is paved with good intentions": When consumers' goals inhibit the minimization of household food waste', *Resources, Conservation and Recycling*, 149(May), pp. 97–105.

FAO (2013) *Food wastage footprint*, *FAO*.

Healthline, Ways to reduce food wastage.

https://www.healthline.com/nutrition/reduce-food-waste

Jain, S. *et al.* (2018) 'Global Food Waste Management: Full Report an implementation guide for cities', *World Biogas Association*, pp. 1–145.

Rutten, M. and Verma, M. (2014) 'The Impacts of Reducing Food Loss in Ghana', *Wageningen, LEI Wageningen UR (University & Research centre), LEI Report 2014*, 35(42), p. 17.

A REVIEW OF THE TYPES AND IMMUNIZATION ROUTES OF VACCINES IN AQUACULTURE

Denicia Atujona, Samule kwasi Sarpong, Gifty Abache
Email: *atujonadenicia@gmail.com*

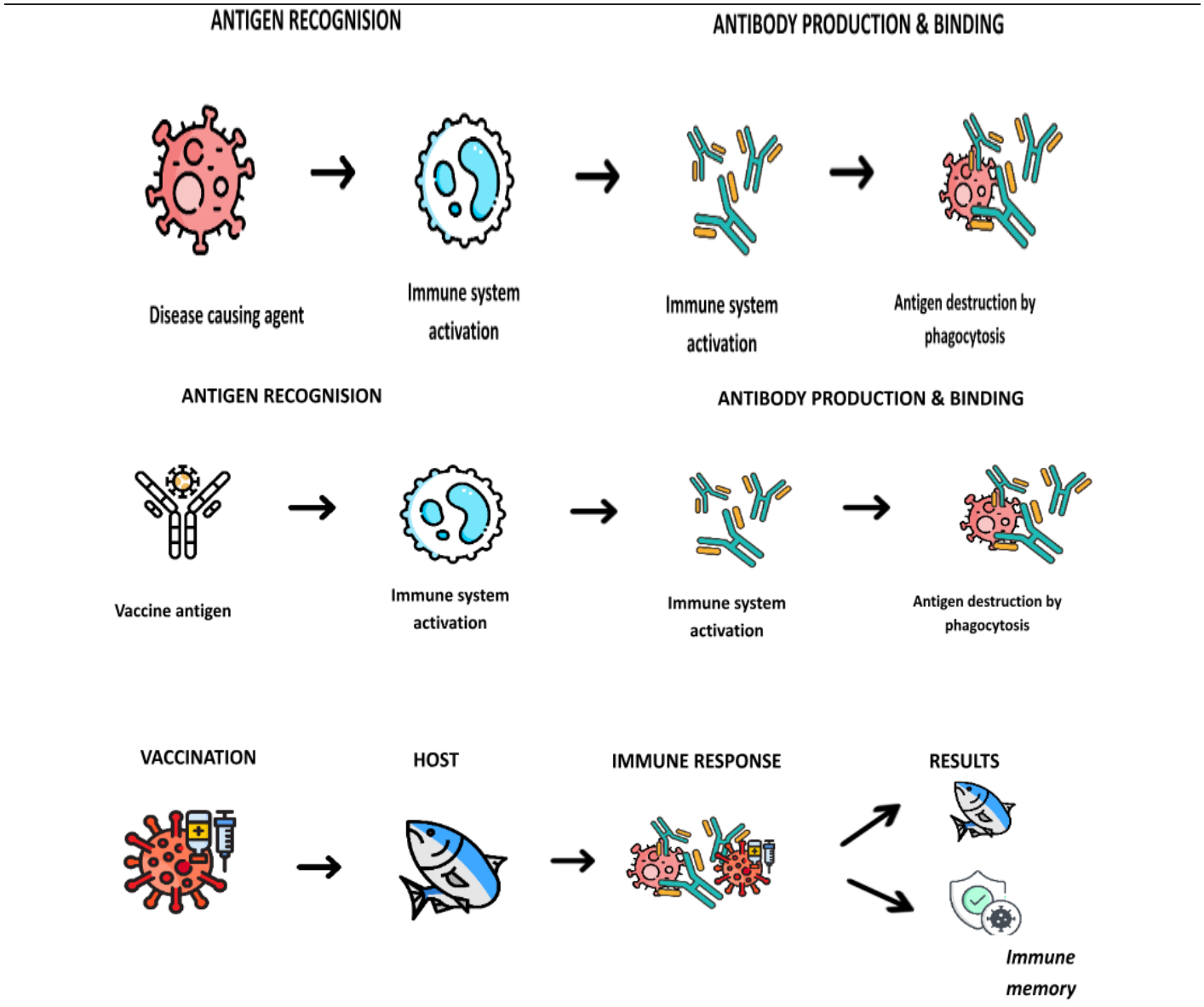


Figure 1: *Vaccine immune enhancement (credit: www.flaticon.com)*

Abstract

Vaccines induce a protective immune response in the host to enhance survival, eliminate or control the spread of infectious agents, as well as moderate clinical diseases. The selection of vaccines is based on fundamental information about the microbes involved, and thus their pathogenicity with environmental considerations. Vaccine development employs a variety of methods that group but do not limit them to live/attenuated vaccines, killed/inactivated vaccines, deoxyribonucleic acid (DNA) vaccines, recombinant vaccines, and subunit vaccines, which is the focus of this review. Vaccines also employ various routes in their administration including injection, immersion, and oral administration, with differences in ability for immune enhancement addressed in this review.

Keywords: Vaccines; Types; Immunization, Aquaculture

Introduction

Vaccines are biological preparations or immunogenic antigens (live, killed, or parts of a pathogenic organism) administered to a host to enhance survival, eliminate, or control the spread of infectious agents, as well as moderate clinical diseases (Atujona, Huang, Wang, Jian, & Cai, 2019). Vaccines have provided tremendous protection against infectious diseases and their complications over the years (Atujona *et al.*, 2019; Hill, 2005;

Rodrigues et al., 2020). They initiate immune responses that mimic the body's natural response to infection, stimulate the body's immune system against foreign agents and activate memory for future sensitivity with limited or no ability to cause disease (Petchimuthu *et al.*, 2018; Plotkin & Immunology, 2010). Vaccines induce immunity following exposure to pathogenic components and confer immune protection against re-infection; immune cells quickly recognize the foreign body, react in response, and produce antibodies to protect the organism from future infection (Sanders & Ponzio, 2017). They inhibit pathogenic microorganisms, improve feed value, aid in enzymatic digestion, have anti-mutagenic and anti-carcinogenic activity, reduce mortality to a bare minimum by conferring protection against infectious diseases in most organisms, and provide environmental protection through reduced antibiotic use (Lorenzen & LaPatra, 2005; Plotkin & immunology, 2010; Wang, 2007). Vaccines elicit specific resistance in an organism through antibody stimulation against a causal agent to achieve protection (McConnell et al., 2011). According to Pillay, an antibody is a type of immunoglobulin, or modified protein, that is produced in response to an antigen and interacts with the antigen (Pillay, 1990). An antigen is any foreign material that can trigger the production of antibodies and interact with those antibodies (Atujona *et al.*, 2019). There are various vaccines with varying degrees of immunity depending on the antigen handling process used in vaccine production, doses used to induce immunity, vaccine coating materials, carriers, adjuvants, vaccine forms (monovalent or multivalent), intended duration and number of immunizations, and the physiological stages of fish development (Du, Hu, Miao, & Chen, 2022). Bacterial vaccines against vibriosis, furunclosis, bacterial kidney disease, columnaris and viral vaccines against Channel catfish virus disease, viral haemorrhagic septicaemia among several have been used in aquaculture (Vaccines for Aquaculture (usda.gov)) (Bøgwald & Dalmo, 2021). Vaccines are administered prior to exposure of pathogens to make for sufficient time to develop immunity, they are administered to healthy organisms because they rely on healthy microbiota present in the intestinal tracts of healthy fish to help with digestion, nutrition, and disease control to produce antibodies that neutralize disease agents, maintain homeostasis, and retain infection memory to elicit protection against future infections and restore functions lost due to infection (Atujona *et al.*, 2019; Deivasigamani, 2007; Yanong, 2003). The nature of a vaccine constituent determines its efficacy and duration of protection; different antigens can be combined to elicit protection against different pathogens (Plotkin & immunology, 2010). Figure 1 depicts vaccine-induced immunity.

Vaccine types used in Aquaculture

Vaccine development and appropriate use determine its immune enhancement ability. Vaccine types used in aquaculture include live/attenuated vaccines, killed/inactivated vaccines, deoxyribonucleic acid (DNA) vaccines, recombinant vaccines, and subunit vaccines among others, and their uses are influenced by several factors including development cost, fish size and numbers to be immunized, immunization purpose among others.

Live/ attenuated vaccines

Attenuated vaccines are the result of organisms being physically and chemically attenuated to lose their virulence without killing them (Assefa & Abunna, 2018). Attenuated vaccines contain live but weakened microbes that induce immune response (persist and metabolize within the host) without causing disease, but are harmful in immunocompromised populations (Vetter, Denizer, Friedland, Krishnan, & Shapiro, 2018). Immune responses conferred by modified live vaccines are cell-mediated and humoral; they are more immunogenic than killed counterparts due to enhanced proliferative ability, reflected in immune responses (Levine & Sztein, 2004). Thus, attenuated vaccines provide better and longer-lasting protection than others against later infection by virulent pathogens without the need for adjuvants (Henderson & Klepac, 2013; Tonheim, Bøgwald, & Dalmo, 2008). Live vaccines have been successful in eliciting an immune response against infectious diseases in catfish, salmons, and several other species of fish; Live aquaculture vaccines licensed for use include Arthrobacter vaccine against bacterial kidney disease in salmonids, *E. ictalurii* vaccine against enteric septicemia of catfish disease, *Flavobacterium columnare* vaccine against columnaris disease in catfish, viral hemorrhagic septicemia virus (VHSV) and Koi herpes virus (KHV) (Dadar *et al.*, 2017; Fuchs, Fichtner, Bergmann, & Mettenleiter, 2011; Gomez-Casado, Estepa, & Coll, 2011; Ma, Bruce, Jones, & Cain, 2019). Research results of (Zhang *et al.*, 2020) and (Liu, Jiao, Ma, Wang, & Zhang, 2018) showed that attenuated *S. lactis* vaccine from a naturally low virulence *S. lactis* strain through erythromycin resistance screening conferred protection to tilapia from *S. lactis* infection by inducing humoral and cellular immune responses in tilapia, significantly increasing the level of specific antibodies. A live attenuated

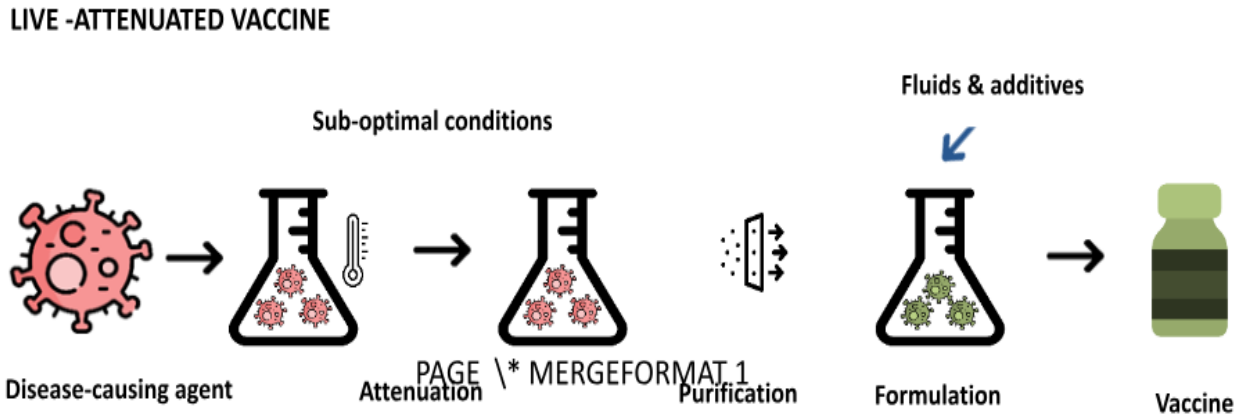


***Figure 2**: Attenuated Vaccine preparation process (credit: www.flaticon.com)*

vaccine created by (Liu *et al.*, 2018) conferred an efficient immune response in *Takifugu rubripes* against vibriosis without a negative impact on fish growth. Results from (Zhang *et al.*, 2020) discovered that a live *A. hydrophila* attenuated vaccine to treat loach vaccine enhanced enzyme activity in serum and skin mucus of loach, as well as an up-regulation in immune-related genes to protect loach from infection of *A. hydrophila*. A live attenuated vaccine against *Vibrio alginolyticus* in zebrafish up-regulated immune-related genes to protect zebrafish against vibriosis (Zhou *et al.*, 2020).

The preparation of an attenuated vaccine is depicted in the image shown in figure 2.

Killed/ inactivated vaccines

Highly virulent pathogenic microorganisms that have been physically or chemically inactivated but retained their immunogenicity to produce particular resistance in organisms after immunization are used in killed vaccines to elicit a host immune response (Ma *et al.*, 2019). Physical inactivation involves the utilization of UV radiation, high-temperature heating, ultrasound, and γ-ray which is complex, expensive, constrained, and unstable (Du *et al.*, 2022). Chemical inactivation on the other hand is a commonly used method of inactivation due to its simplicity, less cost, and reliability. Chemical inactivation renders pathogenic bacteria dormant by using chemicals to destroy their nucleic acids or proteins (Pişkinpaşa & Karasakal, 2021). Formaldehyde is a chemical used to kill viral, bacterial, and parasitic pathogens; it kills microorganisms while preserving protein for immune stimulation (Assefa & Abunna, 2018). Inactivated/killed vaccines are safer compared to live vaccines due to their inability to evolve back into disease-causing conditions, they have a short development period, are stable in storage, and are less expensive (Henderson & Klepac, 2013; Pridgeon & Klesius, 2012; Salgado-Miranda, Loza-Rubio, Rojas-Anaya, & García-Espinosa, 2013). They however require higher doses to confer effective immune enhancement and protection, exhibit a shorter duration of immunity, and as such require booster doses, adjuvants emulsion, and multivalent versions to improve efficacy (Pridgeon, Klesius, & Yildirim-Aksoy, 2013). Several inactivated vaccines have been developed and proven efficacious to confer immune protection including inactivated vaccine for grass carp disease in China (Du *et al.*, 2022; Jiang, 2009). In an experiment by Nguyen (Nguyen *et al.*, 2017), 0.3% formalin-inactivated *Vibrio harveyi* used to immunize grouper conferred 100% relative survival. Formalin inactivated *Haemonchus contortus* elicited significant antibody production when used to vaccinate turbot, and enhanced total serum protein, lysozyme activity, and antimicrobial properties in immunized fish serum (Xu *et al.*, 2019). Inactivated *A. veronii* vaccinated in carp significantly improved immune protection against carp crucian, while adjuvants emulsion improved vaccine efficacy (H. Song *et al.*, 2022).

The risks of inactivation include a decrease in antigen efficacy which leads to inconsistencies, and the need for the adjuvant emulsion to elicit an adequate immune response (Gillund, Dalmo, Tonheim, Seternes, & Myhr, 2008; K. Plant, LaPatra, & Cain, 2009). Also, the culture circumstances, such as the type of media employed and the temperature exposure range, have an impact on the biosafety of such vaccines (Dadar et al., 2017).
The preparation process for inactivated vaccines is depicted in the image shown in figure 3.

Nucleic acid vaccines

Over time, some nucleic acid vaccines have been developed for use in aquaculture; these vaccines combine the beneficial qualities of both live attenuated and subunit vaccinations to provide an effect (Kurath, 2008; Ulmer & Geall, 2016). Nucleic acid vaccines are thought to be extremely simple to produce, and safe to administer because they cannot transform back into a pathogenic state (Ulmer, Mason, Geall, & Mandl, 2012). In DNA and

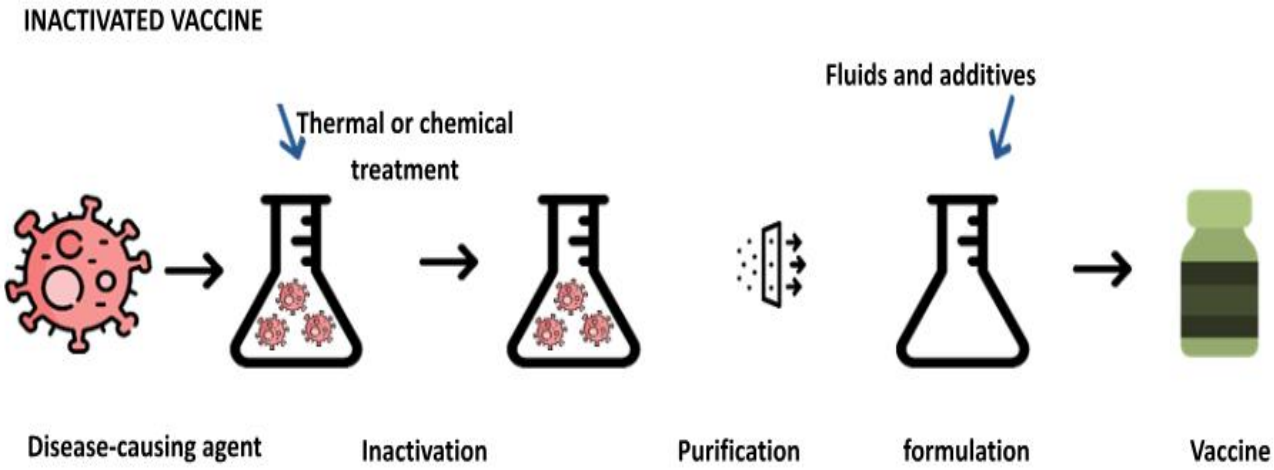


***Figure 3**: Inactivated Vaccine preparation (credit: icons used from www.flaticon.com)*

RNA vaccines, antigen(s) of interest are encoded by DNA and RNA respectively, a plasmid containing a gene producing an antigen protein is injected into an organism's muscle and expressed through the host cell to generate an immunological response to the antigen protein in order to accomplish immune effects (Du *et al.*, 2022; Khan, 2013; Ulmer *et al.*, 2012).

Deoxyribonucleic acid (DNA) vaccines

DNA vaccines use molecular techniques to obtain antigen-coded genes for vaccine development (Lorenzen & LaPatra, 2005). A pDNA consists of a plasmid containing: an E. coli replication origin for plasmid amplification, a potent promoter, usually derived from cytomegalovirus, several cloning sites to insert the gene to be expressed, and an antibiotic serving as a selection marker (Ulmer *et al.*, 1993). The plasmid serves as a means of delivering genes. Before vaccine administration in to host, the pDNA is grown in microorganisms like bacteria, purified, and dissolved in a saline solution (PBS) (Dadar *et al.*, 2017). Results from intramuscular DNA vaccine injection against Ichthyophthirius multifiliis (Ich) in channel catfish, and rainbow trout showed significant up-regulation of immune genes in the head kidney and antibodies in serum during western blot (Dickerson & Findly, 2014; Du *et al.*, 2022). DNA vaccines have many benefits, such as the absence of infection risk, induction of both cell-mediated and humoral immunity, induction of long-lasting immune responses, and induction of elevated cytotoxic T-cell responses (Gurunathan, Klinman, & Seder, 2000). Furthermore, DNA vaccines do not have the same issues as recombinant protein vaccines, such as poor target molecule folding or expensive recombinant protein purification (Kumar & Samant, 2016). Despite the many benefits of DNA vaccines including lower costs, production ease, heat stability, improved quality control, and common processes for the production of different vaccines, some issues about their suitability and capacity such as the potential for anti-DNA antibodies to form, the integration of DNA plasmids into cell genomes, and the ineffectiveness of in vivo cell transfection call for additional research (Běláková, Horynová, Křupka, Weigl, & Raška, 2007), safety for the fish, environment, and consumers must also be addressed before application in aquaculture (Gillund et al., 2008; Lorenzen & LaPatra, 2005).

Toxoid vaccine

A toxoid vaccine is a stable vaccine made from a toxin (poison) that can elicit an immune response in an organism against that toxin (V. Vetter, G. Denizer, L. R. Friedland, J. Krishnan, & M. J. A. o. m. Shapiro, 2018). The viability of the toxin is first destroyed by inactivation before it is introduced into a host to prevent reversion to a virulent or disease-causing state, even though the toxin may trigger disease symptoms (Fulford, Stankiewicz, Fulford, & Stankiewicz, 2020). Toxoid vaccines have several advantages, including safety in use because they cannot cause the diseases they prevent; no possibility of toxoid vaccine antigens spreading to unimmunized individuals because they are not actively multiplying; and finally, they are less susceptible to humidity, temperature, and light fluctuations, making them stable for use in a wide range of environments (Baxter, 2007; V. Vetter, G. Denizer, L. R. Friedland, J. Krishnan, & M. Shapiro, 2018). Toxoid vaccines have several drawbacks, including the need for adjuvant and the possibility of local reactions at vaccinated sites (Baxter, 2007; Salisbury, Ramsay, & Noakes, 2006).

The process of developing toxoid vaccines is depicted in the image shown in figure 4.

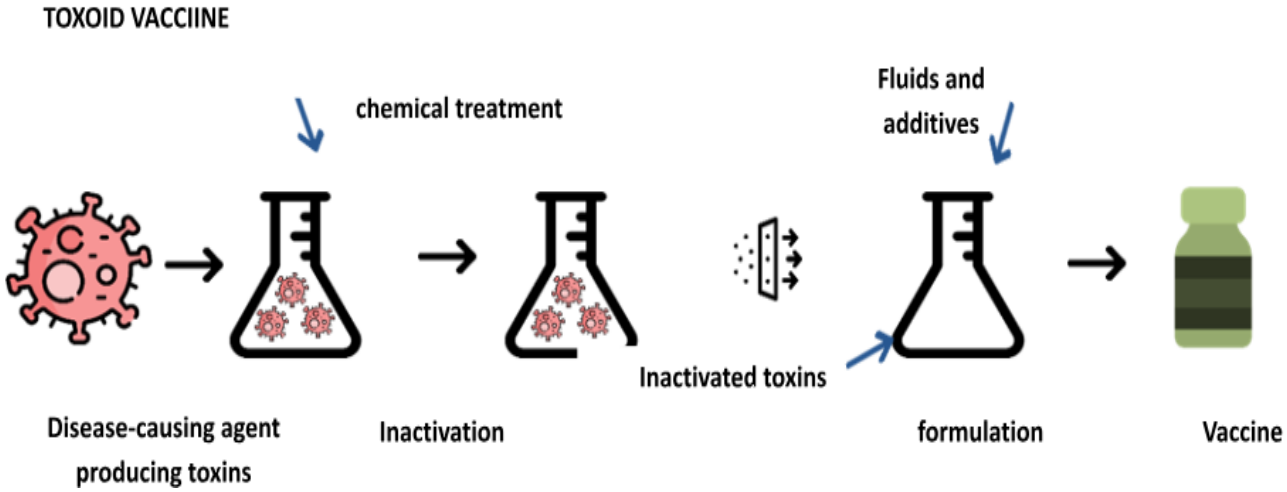


Figure 4. *Toxoid Vaccine preparation (credit: icons used from www.flaticon.com)*

Recombinant Subunit Vaccines

Subunit vaccines are made from a tiny portion of a microorganism (than the whole organism) to stimulate an immune response against the entire organism. Subunit vaccines contain essential antigens from the microbe rather than the entire microbe. Because these vaccines are more specific, the chances of adverse reactions are nil. Recombinant subunit vaccines express immunogenic regions of a pathogen in a host vector to produce vaccine-ready proteins in vitro (Donnelly, Berry, & Ulmer, 2003; Henderson & Klepac, 2013; Tonheim *et al.*, 2008). Recombinant protein vaccines have several advantages over traditional vaccines including lower production costs and safety, most have weak or poor immunogenicity on their own and require adjuvant emulsion to elicit a protective and long-lasting immune response (Atujona *et al.*, 2019; Rollier, Reyes-Sandoval, Cottingham, Ewer, & Hill, 2011). Several recombinant vaccines have been researched in aquaculture and proved efficacious; Atujona et al., 2019 researched on recombinant vaccine against vibriosis in orange-spotted grouper and recorded 90% survival. According to studies, outer membrane proteins (OMPs) have the potential to be a vaccine candidate for fish against infections caused by Vibrio species (anguillarum, mimicus, harveyi, ichthyoenteri) due to their exposed epitopes on the cell surface (Manchanayake, Salleh, Amal, Yasin, & Zamri-Saad, 2023). Also, flagellin and viral capsid proteins are regarded as potential antigens for recombinant vaccines (Makesh & Rajendran, 2022; Rout, de Grahl, Yu, & Reumann, 2022).

The process involved is depicted in the image shown in figure 5.

Route for fish vaccination

Immunization/ vaccination can be achieved via injection, immersion, and oral administration. Immersion is suited for mass immunization especially of juvenile fish due to tender skin which easily absorbs antigens, whereas slightly larger fish can be vaccinated by intraperitonial or intramuscular injection of adjuvant emulsified vaccines for enhanced immunity (Du *et al.*, 2022). Oral immunization is ideal for all fish types small and large, and all species, it is simple, fast, and less stressful when administering to fish (Bøgwald & Dalmo, 2021). Oral vaccines compared to injectables are less effective due to a weaker response from the intestinal mucosal system as a result of antigen destruction in the digestive tract (Du *et al.*, 2022).

Injection vaccination

Vaccination by injection is done intraperitoneally and intramuscularly and is the most efficient form of immunization. Injections ensure that each inoculated fish receives a similar dose of the vaccine to elicit an immunological response from the body, giving the immunized fish consistent and long-lasting immune protection. Its shortfalls however include handling difficulties and inconvenience immunizing small fish under 20g though these are usually the most prone to disease (Du, Hu, Miao, & Chen, 2022), also handling anesthesia and injection procedures both stress the fish and enhance labor costs when dealing with large numbers of fish (Liang, Peng, & Chiou, 2016; Sudheesh & Cain, 2017). Several vaccines administered by injection have elicited immunity in fish including works in (Ramírez-Paredes *et al.*, 2019) which successfully prevented Francisellosis in red Nile tilapia. Injection vaccination also protected turbot and grouper from vibriosis, it was discovered that intraperitoneal injection of vaccine promoted humoral immunity and improved the innate immune response to offer effective protection for a long time (Atujona, Huang, Wang, Jian, & Cai, 2019; Xu *et al.*, 2019).

Immunization by immersion

For immersion immunization, the mucosal immune system of fish can quickly and effectively get activated by antigens taken up by mucosal

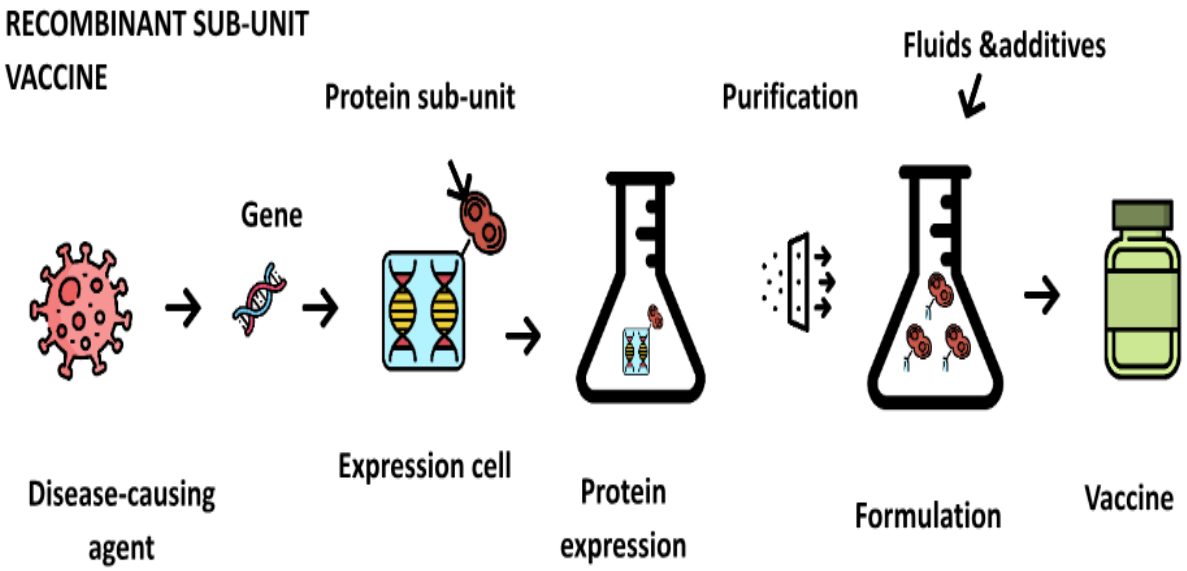


***Figure 5**: I Recombinant Vaccine preparation (credit: icons used from www.flaticon.com)*

tissues like the skin, lateral line, gills, and gastrointestinal tract (Khimmakthong *et al.*, 2013). Later, the antigens spread to the blood, spleen, kidney, and other systemic immune tissues through the circulation of blood to cause a systemic immune response (Du, Tang, Sheng, Xing, & Zhan, 2017). To influence antigen infiltration into the fish via a change in osmotic pressure, the fish is submerged in a 3% to 5% salt solution for 5 minutes before being moved to the vaccine solution for immersion (Gao, Tang, Sheng, Xing, & Zhan, 2015; Huising *et al.*, 2003). Immersion is less stressful with reduced chances of mechanical damage to fish due to reduced handling. Immersion vaccination has been applied in Anguilla japonica (Y.-L. Song & Kou, 1981), Atlantic cod (Mikkelsen, Lund, Larsen, & Seppola, 2011), grouper (Liang *et al.*, 2016), Crucian carp (Aonullah, Nuryati, & Murtini, 2017), and rainbow trout (Skov *et al.*, 2018). The immunological response of immersion vaccination is lower than injection vaccination because the uptake of antigen by immersion is limited (Bøgwald & Dalmo, 2021). Immersion is done in various ways including direct immersion (DI), hypertonic immersion (HI); flushing; and spraying (Rombout & Kiron, 2014).

Oral vaccination

Oral vaccination is suitable for inactivated vaccines, nucleic acid vaccines and live attenuated vaccines (Du *et al.*, 2022). They reduce mechanical injury, stress, and labour cost, and are not constrained to the age and size of the animal (Sukkarun *et al.*, 2022). Oral vaccination can carry out its intended immunological function on successfully preventing digestive fluid from destroying the antigen components of the vaccine as they reach the gut lymphoid tissue achieved by biofilm (Ko, Lee, Lee, Kim, & Kang, 2017; Liu *et al.*, 2017). The immunological impact of the vaccination can be greatly enhanced after being encapsulated with sodium alginate because the vaccine is vulnerable to digestion tract enzyme degradation, but the immense cost of the enclosed material makes it unrealistic for practical use (Su & Chen, 2021). Oral vaccines can stimulate cellular and humoral immune responses at mucosal and systematic sites for broader and lasting protection (Ramirez, Sharpe, & Peppas, 2017).

Reference

Aonullah, A. A., Nuryati, S., & Murtini, S. J. A. R. (2017). Efficacy of koi herpesvirus DNA vaccine administration by immersion method on Cyprinus carpio field scale culture. *48*(6), 2655-2662.

Assefa, A., & Abunna, F. (2018). Maintenance of fish health in aquaculture: review of epidemiological approaches for prevention and control of infectious disease of fish. *J Veterinary medicine international, 2018*.

Atujona, D., Huang, Y., Wang, Z., Jian, J., & Cai, S. (2019). Vibrio harveyi (VirB11) recombinant vaccine development against vibriosis in orange-spotted grouper (Epinephelus coioides). *J Aquaculture Research, 50*(9), 2628-2634.

Baxter, D. (2007). Active and passive immunity, vaccine types, excipients and licensing. *J Occupational medicine, 57*(8), 552-556.

Běláková, J., Horynová, M., Křupka, M., Weigl, E., & Raška, M. (2007). DNA vaccines: are they still just a powerful tool for the future? *J Archivum immunologiae et therapiae experimentalis, 55*, 387-398.

Bøgwald, J., & Dalmo, R. A. (2021). Protection of teleost fish against infectious diseases through oral administration of vaccines: update 2021. *J International Journal of Molecular Sciences, 22*(20), 10932.

Chettri, J. K., Jaafar, R. M., Skov, J., Kania, P. W., Dalsgaard, I., & Buchmann, K. J. A. (2015). Booster immersion vaccination using diluted Yersinia ruckeri bacterin confers protection against ERM in rainbow trout. *440*, 1-5.

Dadar, M., Dhama, K., Vakharia, V. N., Hoseinifar, S. H., Karthik, K., Tiwari, R., . . . Joshi, S. K. (2017). Advances in aquaculture vaccines against fish pathogens: global status and current trends. *J Reviews in Fisheries Science Aquaculture*, *25*(3), 184-217.

Deivasigamani, B. (2007). Structure of immune organ in edible catfish, Mystus gulio. *J Journal of Environmental Biology*, *28*(4), 757.

Dickerson, H., & Findly, R. (2014). Immunity to Ichthyophthirius infections in fish: a synopsis. *J Developmental Comparative Immunology*, *43*(2), 290-299.

Donnelly, J., Berry, K., & Ulmer, J. B. (2003). Technical and regulatory hurdles for DNA vaccines. *J International journal for parasitology*, *33*(5-6), 457-467.

Du, Y., Hu, X., Miao, L., & Chen, J. (2022). Current status and development prospects of aquatic vaccines. *J Frontiers in Immunology*, *13*.

Du, Y., Tang, X., Sheng, X., Xing, J., & Zhan, W. (2015). Immune response of flounder (Paralichthys olivaceus) was associated with the concentration of inactivated Edwardsiella tarda and immersion time. *J Veterinary immunology immunopathology*, *167*(1-2), 44-50.

Du, Y., Tang, X., Sheng, X., Xing, J., & Zhan, W. (2017). The influence of concentration of inactivated Edwardsiella tarda bacterin and immersion time on antigen uptake and expression of immune-related genes in Japanese flounder (Paralichthys olivaceus). *J Microbial pathogenesis*, *103*, 19-28.

Fuchs, W., Fichtner, D., Bergmann, S. M., & Mettenleiter, T. C. (2011). Generation and characterization of koi herpesvirus recombinants lacking viral enzymes of nucleotide metabolism. *J Archives of virology*, *156*, 1059-1063.

Gao, Y.-L., Tang, X.-Q., Sheng, X.-Z., Xing, J., & Zhan, W.-B. J. D. o. A. O. (2015). Immune responses of flounder Paralichthys olivaceus vaccinated by immersion of formalin inactivated.

Edwardsiella tarda following hyperosmotic treatment. *116*(2), 111-120.

Gillund, F., Dalmo, R., Tonheim, T. C., Seternes, T., & Myhr, A. I. (2008). DNA vaccination in aquaculture—expert judgments of impacts on environment and fish health. *J Aquaculture Research*, *284*(1-4), 25-34.

Gomez-Casado, E., Estepa, A., & Coll, J. (2011). A comparative review on European-farmed finfish RNA viruses and their vaccines. *J Vaccine*, *29*(15), 2657-2671.

Gurunathan, S., Klinman, D. M., & Seder, R. A. (2000). DNA vaccines: immunology, application, and optimization. *J Annual review of immunology*, *18*(1), 927-974.

Henderson, D., & Klepac, P. (2013). Lessons from the eradication of smallpox: an interview with DA Henderson. *J Philosophical Transactions of the Royal Society B: Biological Sciences*, *368*(1623), 20130113.

Hill, B. (2005). The need for effective disease control in international aquaculture. *J Developments in biologicals*, *121*, 3-12.

Huising, M. O., Guichelaar, T., Hoek, C., Verburg-van Kemenade, B. L., Flik, G., Savelkoul, H. F., & Rombout, J. H. J. V. (2003). Increased efficacy of immersion vaccination in fish with hyperosmotic pretreatment. *21*(27-30), 4178-4193.

Jiang, Y. (2009). Hemorrhagic disease of grass carp: status of outbreaks, diagnosis, surveillance, and research.

Khan, K. H. (2013). DNA vaccines: roles against diseases. *J Germs*, *3*(1), 26.

Ko, E.-J., Lee, Y.-T., Lee, Y., Kim, K.-H., & Kang, S.-M. J. I. n. (2017). Distinct effects of monophosphoryl lipid A, oligodeoxynucleotide CpG, and combination adjuvants on modulating innate and adaptive immune responses to influenza vaccination. *17*(5), 326-342.

Kumar, A., & Samant, M. (2016). DNA vaccine against visceral leishmaniasis: a promising approach for prevention and control. *J Parasite immunology*, *38*(5), 273-281.

Kurath, G. (2008). Biotechnology and DNA vaccines for aquatic animals. *J Revue scientifique et technique-Office international des épizooties*, *27*(1), 175.

Levine, M. M., & Sztein, M. B. (2004). Vaccine development strategies for improving immunization: the role of modern immunology. *J Nature immunology*, *5*(5), 460-464.

Liang, H.-J., Peng, R.-H., & Chiou, P. P. (2016). Development of immersion subunit vaccine against grouper iridovirus (GIV).

Linh, N. V., Sangpo, P., Senapin, S., Thapinta, A., Panphut, W., St-Hilaire, S., . . . Immunology, S. (2022). Pre-treatment of Nile tilapia (Oreochromis niloticus) with ozone nanobubbles improve efficacy of heat-killed Streptococcus agalactiae immersion vaccine. *123*, 229-237.

Liu, X., Jiao, C., Ma, Y., Wang, Q., & Zhang, Y. (2018). A live attenuated Vibrio anguillarum vaccine induces efficient immunoprotection in Tiger puffer (Takifugu rubripes). *J Vaccine*, *36*(11), 1460-1466.

Liu, X., Zhang, H., Jiao, C., Liu, Q., Zhang, Y., & Xiao, J. J. V. (2017). Flagellin enhances the immunoprotection of formalin

inactivated Edwardsiella tarda vaccine in turbot. *35*(2), 369-374.

Lorenzen, N., & LaPatra, S. (2005). DNA vaccines for aquacultured fish. *J Revue scientifique et technique, 24*(1), 201-213.

Ma, J., Bruce, T. J., Jones, E. M., & Cain, K. D. (2019). A review of fish vaccine development strategies: Conventional methods and modern biotechnological approaches. *J Microorganisms, 7*(11), 569.

Makesh, M., & Rajendran, K. (2022). *Fish immune system and vaccines*: Springer.

Manchanayake, T., Salleh, A., Amal, M. N. A., Yasin, I. S. M., & Zamri-Saad, M. (2023). Pathology and pathogenesis of Vibrio infection in fish: A review. *J Aquaculture Reports, 28*, 101459.

McConnell, M. J., Domínguez-Herrera, J., Smani, Y., López-Rojas, R., Docobo-Pérez, F., & Pachón, J. (2011). Vaccination with outer membrane complexes elicits rapid protective immunity to multidrug-resistant Acinetobacter baumannii. *J Infection immunity, 79*(1), 518-526.

Mikkelsen, H., Lund, V., Larsen, R., & Seppola, M. (2011). Vibriosis vaccines based on various sero-subgroups of Vibrio anguillarum O2 induce specific protection in Atlantic cod (Gadus morhua L.) juveniles. *J Fish shellfish immunology, 30*(1), 330-339.

Nguyen, H. T., Nguyen, T. T. T., Tsai, M.-A., Ya-Zhen, E., Wang, P.-C., & Chen, S.-C. (2017). A formalin-inactivated vaccine provides good protection against Vibrio harveyi infection in orange-spotted grouper (Epinephelus coioides). *J Fish shellfish immunology, 65*, 118-126.

Petchimuthu, M., George, M. R., John, K. R., Kaviarasu, D., Dinesh, R., & Studies, Z. (2018). Occurrence of parasites in aquaculture systems of South Tamil Nadu. *J Journal of Entomology, 6*(2), 283-286.

Pillay, T. V. R. (1990). *Aquaculture: principles and practices*: fishing news books.

Pişkinpaşa, N., & Karasakal, Ö. F. (2021). Introduction to Vaccination. In *Synthetic Peptide Vaccine Models* (pp. 10-25): CRC Press.

Plant, K., LaPatra, S., & Cain, K. (2009). Vaccination of rainbow trout, Oncorhynchus mykiss (Walbaum), with recombinant and DNA vaccines produced to Flavobacterium psychrophilum heat shock proteins 60 and 70. *J Journal of Fish Diseases, 32*(6), 521-534.

Plant, K. P., & LaPatra, S. E. (2011). Advances in fish vaccine delivery. *J Developmental Comparative Immunology, 35*(12), 1256-1262.

Plotkin, S. A., & immunology, v. (2010). Correlates of protection induced by vaccination. *J Clinical, 17*(7), 1055-1065.

Pridgeon, J. W., & Klesius, P. H. (2012). Major bacterial diseases in aquaculture and their vaccine development. *J CABI Reviews* (2012), 1-16.

Pridgeon, J. W., Klesius, P. H., & Yildirim-Aksoy, M. (2013). Attempt to develop live attenuated bacterial vaccines by selecting resistance to gossypol, proflavine hemisulfate, novobiocin, or ciprofloxacin. *J Vaccine, 31*(18), 2222-2230.

Ramírez-Paredes, J. G., Mendoza-Roldan, M. A., Lopez-Jimena, B., Shahin, K., Metselaar, M., Thompson, K. D., . . . Adams, A. (2019). Whole cell inactivated autogenous vaccine effectively protects red Nile tilapia (Oreochromis niloticus) against francisellosis via intraperitoneal injection. *J Journal of Fish Diseases, 42*(8), 1191-1200.

Ramirez, J. E. V., Sharpe, L. A., & Peppas, N. A. J. A. d. d. r. (2017). Current state and challenges in developing oral vaccines. *114*, 116-131.

Rodrigues, M. V., Zanuzzo, F. S., Koch, J. F. A., de Oliveira, C. A. F., Sima, P., & Vetvicka, V. (2020). Development of fish immunity and the role of β-glucan in immune responses. *J Molecules, 25*(22), 5378.

Rollier, C. S., Reyes-Sandoval, A., Cottingham, M. G., Ewer, K., & Hill, A. V. (2011). Viral vectors as vaccine platforms: deployment in sight. *J Current Opinion in Immunology, 23*(3), 377-382.

Rombout, J. H., & Kiron, V. (2014). Mucosal vaccination of fish. *J Fish vaccination*, 56-67.

Rout, S. S., de Grahl, I., Yu, X., & Reumann, S. (2022). Production of a viral surface protein in Nannochloropsis oceanica for fish vaccination against infectious pancreatic necrosis virus. *J Applied Microbiology Biotechnology, 106*(19-20), 6535-6549.

Salgado-Miranda, C., Loza-Rubio, E., Rojas-Anaya, E., & García-Espinosa, G. (2013). Viral vaccines for bony fish: past, present and future. *J Expert review of vaccines, 12*(5), 567-578.

Salisbury, D., Ramsay, M., & Noakes, K. (2006). Immunisation Against Infectious Diseases available at http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAn dGuidance. *J DH 079917* .

Sanders, J. W., & Ponzio, T. A. (2017). Vectored immunoprophylaxis: an emerging adjunct to traditional vaccination. *J Tropical Diseases, Travel Medicine Vaccines, 3*(1), 1-6.

Skov, J., Chettri, J. K., Jaafar, R. M., Kania, P. W., Dalsgaard, I., & Buchmann, K. (2018). Effects of soluble immunostimulants on mucosal immune responses in rainbow trout immersion-vaccinated against Yersinia ruckeri. *J Aquaculture, 492*, 237-246.

Song, H., Zhang, S., Yang, B., Liu, Y., Kang, Y., Li, Y., . . . Shan, X. (2022). Effects of four different adjuvants separately combined with Aeromonas veronii inactivated vaccine on haematoimmunological state, enzymatic activity, inflammatory response and disease resistance in crucian carp. *J Fish shellfish immunology*, *120*, 658-673.

Song, Y.-L., & Kou, G.-H. (1981). The immuno-responses of eel (Anguilla japonica) against Edwardsiella anguillimortifera as studied by the immersion method. *J Fish Pathology*, *15*(3-4), 249-255.

Su, F.-J., & Chen, M.-M. J. V. (2021). Protective efficacy of novel oral biofilm vaccines against Lactococcus garvieae infection in mullet, Mugil cephalus. *9*(8), 844.

Sudheesh, P. S., & Cain, K. D. (2017). Prospects and challenges of developing and commercializing immersion vaccines for aquaculture. *J International Biology Review*, *1*(1).

Sukkarun, P., Kitiyodom, S., Yostawornkul, J., Chaiin, P., Yata, T., Rodkhum, C., . . . Immunology, S. (2022). Chitosan-polymer based nanovaccine as promising immersion vaccine against Aeromonas veronii challenge in red tilapia (Oreochromis sp.). *129*, 30-35.

Tonheim, T. C., Bøgwald, J., & Dalmo, R. A. (2008). What happens to the DNA vaccine in fish? A review of current knowledge. *J Fish shellfish immunology*, *25*(1-2), 1-18.

Ulmer, J. B., Donnelly, J. J., Parker, S. E., Rhodes, G. H., Felgner, P. L., Dwarki, V., . . . Friedman, A. (1993). Heterologous protection against influenza by injection of DNA encoding a viral protein. *J Science*, *259*(5102), 1745-1749.

Ulmer, J. B., & Geall, A. J. (2016). Recent innovations in mRNA vaccines. *J Current Opinion in Immunology*, *41*, 18-22.

Ulmer, J. B., Mason, P. W., Geall, A., & Mandl, C. W. (2012). RNA-based vaccines. *J Vaccine*, *30*(30), 4414-4418.

Vetter, V., Denizer, G., Friedland, L. R., Krishnan, J., & Shapiro, M. (2018). Understanding modern-day vaccines: what you need to know. *J Annals of medicine*, *50*(2), 110-120.

Vinay, T., & Bedekar, M. K. (2022). Methods of Vaccine Delivery. In *Fish immune system and vaccines* (pp. 217-230): Springer.

Wang, Y.-B. (2007). Effect of probiotics on growth performance and digestive enzyme activity of the shrimp Penaeus vannamei. *J Aquaculture Research*, *269*(1-4), 259-264.

Xu, W., Jiao, C., Bao, P., Liu, Q., Wang, P., Zhang, R., . . . Zhang, Y. (2019). Efficacy of Montanide™ ISA 763 A VG as aquatic adjuvant administrated with an inactivated Vibrio harveyi vaccine in turbot (Scophthalmus maximus L.). *J Fish shellfish immunology*, *84*, 56-61.

Yanong, R. P. (2003). Fish health management considerations in recirculating aquaculture systems–part 2: pathogens. *J Circular*, *121*, 1-8.

Zhang, D., Gao, Y., Li, Q., Ke, X., Liu, Z., Lu, M., & Shi, C. (2020). An effective live attenuated vaccine against Streptococcus agalactiae infection in farmed Nile tilapia (Oreochromis niloticus). *J Fish shellfish immunology*, *98*, 853-859.

Zhou, S., Tu, X., Pang, H., Hoare, R., Monaghan, S. J., Luo, J., & Jian, J. (2020). A T3SS regulator mutant of Vibrio alginolyticus affects antibiotic susceptibilities and provides significant protection to Danio rerio as a live attenuated vaccine. *J Frontiers in Cellular Infection Microbiology*, *10*, 183.

THE ROLE OF FOOD SCIENCE IN HUMAN NUTRITION

Aboagye Stephanie Adomaa (BSc)
Institution: *Department of Food Science and Technology, KNUST*
Email: *aboagyestephanie65@gmail.com*

Introduction

Food provides nutrients for our body to function well. The role of food science in human nutrition includes food processing, food fortification, and enrichment with nutrients which are not present in food or lost during the processing, preservation, and storage of food.

This article talks of the essence of food science in human nutrition highlighting the essence of taking our diets seriously to benefit from all the nutrients in our food that the body needs to function properly.

Food is very essential to humans. Food provides the body with the energy it needs to function through nutrients absorbed from the food. Food science is a discipline in which the principles of biological and physical sciences are used to study the nature of foods, the causes of their deterioration, and the principles underlying the processing and preparation of food. According to Berdanier *et al.* (2008), food can be defined as any material that provides nourishment for the growth and maintenance of life, including repairing tissues, producing hormones, and regulating body temperature. Science according to Teixeira *et al.* (2012), is the systematic study of the structure and behaviour of the physical and natural world through observation, experimentation, and the testing of theories against the evidence obtained.

From this, Food science can be defined as the systematic study of the structure and behaviour of the physical and natural material that provides nourishment for the growth and maintenance of life. Food science is also the study of the chemical and physical properties of foods and of changes that may occur during processing and storage.

Nutrition is the process of providing or obtaining the food necessary for health and growth. Food science ensures that food manufacturing processes conform to government, processing, consumer, and industry standards. Food Science and Nutrition is the science behind the food we eat. From the effect, food has on our behaviour and well-being, to new applications in food development, processing, compliance, and food safety. Nutrition is the major reason for food processing, and this is because the core reason for processing food is to allow us to get good value from the food. This is why most foods that lose some of their nutrients during processing are enriched or fortified with such nutrients Nutrient is a chemical compound (such as protein, fat, carbohydrate, vitamin, or mineral) contained in foods. These compounds are used by the body to function and grow. There are 7 of them which are

proteins, carbohydrates, vitamins, minerals, fats and oils, dietary fibre, and water. Food science helps us to understand the science behind these nutrients. It helps you to know that some foods contain certain nutrients like vitamins that are water soluble and as such must not be boiled before eating or when boiled the stock must be eaten with the food to prevent nutrient loss. It also helps you to know that proteins can denature when exposed to too much heat and when that happens you end up getting little of the proteins from a portion of food or losing it all and with that, we are only eating to fill our tummies with no nutrients. Nutrients are very important because they help to boost our immune systems which helps us stay stronger at all times.

Food science is concerned with all quality and safety aspects of foods before a person consumes them, while nutrition is related to how the body uses foods after we eat them to promote and maintain our health (Floros *et al.,* 2010). While food science focuses on the manufacturing, processing, and production of food, nutrition focuses on the maintenance of good health and the well-being of populations (Floros *et al.,*2010)Some of the roles of foods science in human nutrition include: food processing as it is shown variable ways in which one food commodity can be processed into different forms; food fortification and enrichment in which nutrients that were not present or that were present but lost during processing are added to the food at even greater levels; and also food preservation and storage which show us how to keep our foods safe for future use.

Talking of fortification, it is defined as the practice of adding vitamins and minerals to commonly consumed foods during processing to increase their nutritional value. It is a proven, safe and cost-effective strategy for improving diets and for the prevention and control of micronutrient deficiencies. When foods are fortified, they can help maintain healthy micronutrient levels to keep your bones strong, help your digestion, and prevent heart issues. They also help with the dietary needs of the body.

An enriched food is a food in which nutrients that were lost during processing are added back in, compared to fortification which adds additional micronutrients not present (or present in small amounts) prior to processing.

The five enrichment nutrients are defined by the Food and Drug Administration (FDA) and include thiamine (vitamin B1, thiamine mononitrate, or thiamine hydrochloride); riboflavin (vitamin B2); niacin (vitamin B3 or niacin amide); folic acid (folate); and iron (reduced iron, ferrous sulphate, or ferric orthophosphate) (Saade *et al.,*2020).

Food supplements are known to be concentrated sources of nutrients or other substances with a nutritional or physiological effect that are marketed in "dose" form (Vettorazzi *et al.,* 2020). Their function is to correct nutritional deficiencies, maintain an adequate intake of certain nutrients, or to support specific physiological functions A wide range of nutrients and other ingredients might be present in food supplements, including, but not limited to, vitamins, minerals, amino acids, essential fatty acids, fibre and various plants and herbal extracts.

Conclusion

The role of food science in nutrition is an interesting and important and this is because if we get to see the importance of food science (the science behind what we eat) in our diet, we wouldn't have to make medicine our food but food would be our medicine and this would be because we wouldn't subject our food to conditions that would cause us to lose the important nutrients we need for our growth of our body.

References

Berdanier, C.D., Berdanier, L.A. and Zempleni, J., 2008. Advanced nutrition: macronutrients, micronutrients, and metabolism. CRC press.

Teixeira, P.J., Carraça, E.V., Markland, D., Silva, M.N. and Ryan, R.M., 2012. Exercise, physical activity, and self-determination theory: a systematic review. International journal of behavioural nutrition and physical activity, 9(1), pp.1-30.

Floros, J.D., Newsome, R., Fisher, W., Barbosa-Cánovas, G.V., Chen, H., Dunne, C.P., German, J.B., Hall, R.L., Heldman, D.R., Karwe, M.V. and Knabel, S.J., 2010. Feeding the world today and tomorrow: the importance of food science and technology: an IFT scientific review. Comprehensive Reviews in Food Science and Food Safety, 9(5), pp.572-599.

Saade, C. and Arijaje, E.O., 2020. Fortification. In Breakfast Cereals and How They Are Made (pp. 343-359). AACC International Press.

Vettorazzi, A., López de Cerain, A., Sanz-Serrano, J., Gil, A.G. and Azqueta, A., 2020. European regulatory framework and safety assessment of food-related bioactive compounds. Nutrients, 12(3), p.613

HEALTH BENEFIT OF BLUEBERRIES

Josephine Cudjoe and Dorothy Eshun
Institution: *Department of Food Science and Technology, KNUST*
Email: *cudjoejosephine21@gmail.com / eshun.dorophina@gmail.com*
Tel: *0540666296/ 0556738935*

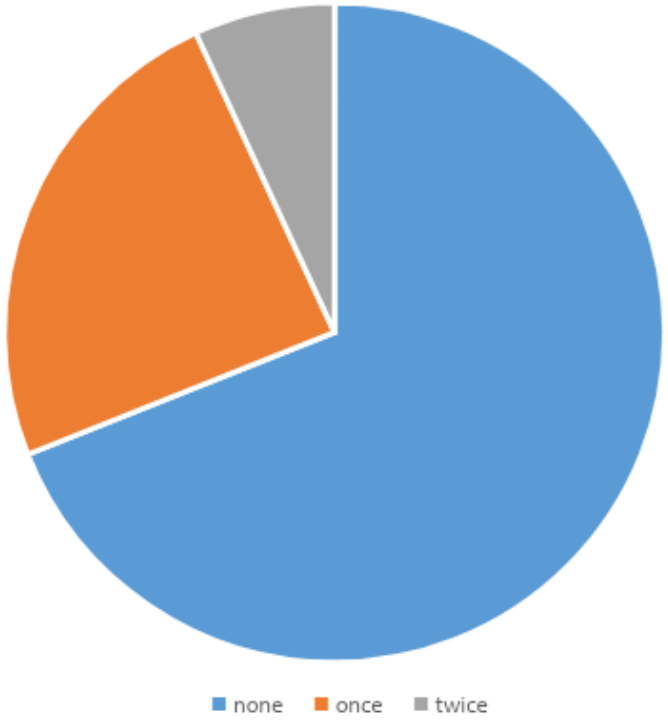


Chart showing the intake of Blueberries as part of Diet per Week

Abstract

Blueberries are a widely distributed and widespread group of perennial flowering plants with blue or purple berries. According to a report by food and agriculture organization (FAO), the country with the highest per capita consumption of blueberries is Iceland followed by Denmark, Australia and Canada. Blueberries are known to have a number of health benefits. They are high in antioxidants which help protect against cancer, heart disease etc. Blueberries can be used in the production of foods such as low sugar jams and jellies for people with diabetes, making smoothies and healthy snacks that are high in fiber and low in calories.

Health Benefit of Blueberries

Blueberries are a widely distributed and widespread group of perennial flowering plants with blue or purple berries. They are classified in the section Cyanococcus within the genus Vaccinium (Lisa J. Rowland; Freddi A. Hammerschlag (2005)). Commercial blueberries both wild (lowbush) and cultivated (highbush) are all native to North America. The highbush varieties were introduced into Europe during the 1930s (Naumann, W. D. (1993)). Countries like united states, Canada and Chile are the largest producers of blueberries. According to a report by food and agriculture organization (FAO), the country with the highest per capita consumption of blueberries is Iceland followed by Denmark, Australia, and Canada. Blueberries are known to have a number of health benefits. They are high in antioxidants which help protect against cancer, heart disease etc. they are also good source of fibre which help to regulate digestion and lower cholesterol levels. They are also low in calories and high in vitamin C. Lack of blueberries increases the risk of cancer and heart diseases. Eating blueberries regularly help keep your body health and reduce your risk of these diseases.

However, consuming excessive amount of blueberries can lead to gastrointestinal issues such as diarrhoea and stomach cramps. It can also lead to weight gain since it contains natural sugar therefore it is recommended to be taken in moderate amount.

Blueberries can be used in the production of foods such as low sugar jams and jellies for people with diabetes, making smoothies and healthy snacks that are high in fibre and low in calories.

We conducted a survey in some universities in Ghana on the intake of blueberry as part of their diet.

Based on the data collected, most of the student have not eaten blueberries before, some include it once or twice in their diet. Reason being that it is expensive, not easy to get, some not liking, and majority have not even heard of blueberries.

Conclusion

All these problems can be solved by educating individual on the health benefit of including blueberries in their diet.

References

Lisa J. Rowland; Freddi A. Hammerschlag (2005). Richard E. Litz (ed.). Vaccinium spp. (8.1: Blueberry). In: Biotechnology of Fruit and Nut Crops: Volume 29 of Biotechnology in Agriculture Series. CABI. ISBN 0-85199-066-5. Archived from the original on December 12, 2020. Retrieved September 21, 2020.

Naumann, W. D. (1993). "Overview of the Vaccinium Industry in Western Europe". In K. A. Clayton-Greene (ed.). Fifth International Symposium on Vaccinium Culture. Wageningen, the Netherlands: International Society for HorticulturalScience.pp. 53–58. ISBN 978-90-6605-475-2. OCLC 29663461. Archived from the original on March 11, 2007. Retrieved August 25, 2006.

DEBUNKING THE MYTH SURROUNDING CASHEW APPLES

Victoria Afi Ahanogbe and Emmanuel Aning

Institution: *Department of Food Science and Technology, Faculty of Biosciences, KNUST, Kumasi, Ghana*

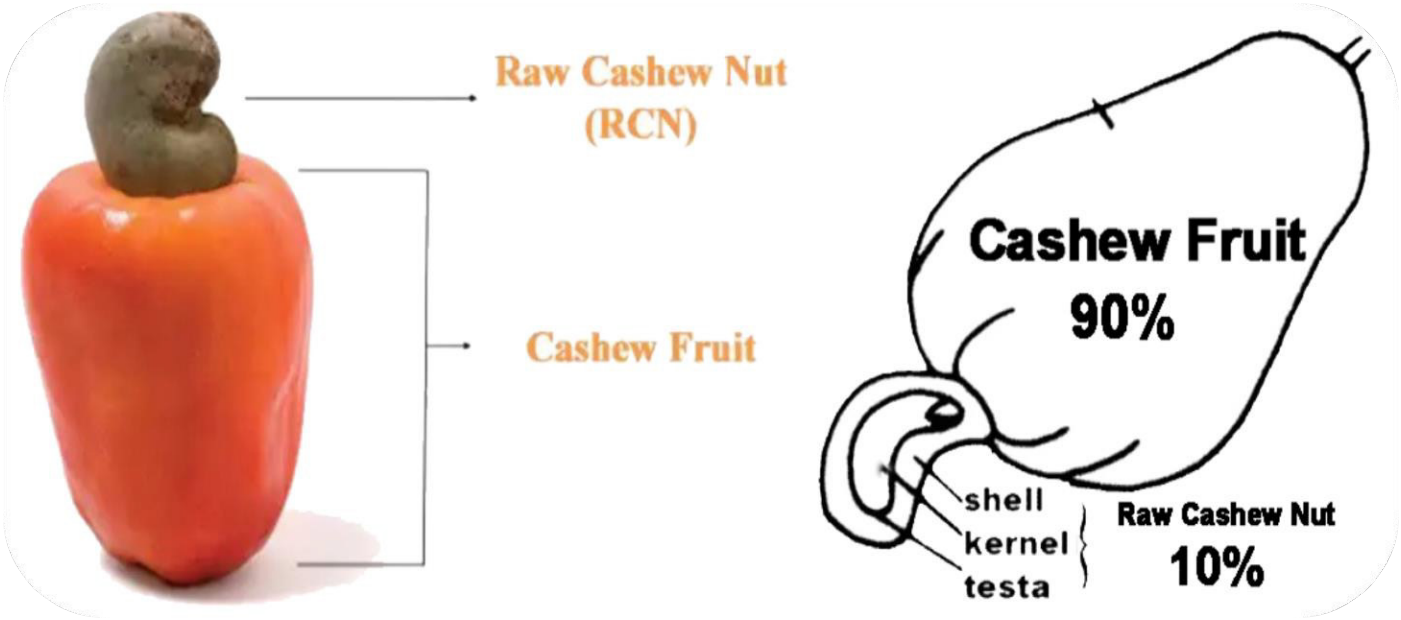


Figure 1: *Part of Cashew Fruit (Kimmy farms,2021)*

Abstract

The article "Debunking the Myth Surrounding Cashew Apples" aims to address and dispel prevailing misconceptions surrounding cashew apples. It provides an accurate understanding of the safety of cashew apples to human health and addresses the beliefs that have led to fear and uncertainty among individuals. The article highlights the historical and cultural context of cashew cultivation and the reasons behind the underutilization of cashew apples. It then examines the myth that cashew apples are poisonous, presenting scientific evidence to counter these claims. The article emphasizes the lack of empirical data supporting the myth and discusses the nutritional value, culinary uses, and medicinal properties of cashew apples. Overall, the article seeks to promote accurate information about cashew apples and encourage their rightful place in the diet and culinary traditions of communities where they are grown.

Introduction

Cashew (Anacardium occidentale) is a cash crop found in India, Brazil, Vietnam and several West African countries like Benin, Cote d'Ivoire, Guinea-Bissau, Nigeria, and Ghana. Currently, Cote d'Ivoire holds the top position as the foremost producer of cashews in Africa and ranks third globally in terms of production. Cashew plantation was introduced as a means to combat desertification and erosion, cashew gained recognition for its nuts used in extraction of oil and the production of value-added products. Ghana has emerged as a significant contributor to the international cashew market, producing around 171,924 metric tons of nuts in 2019 (Akyereko *et al.*, 2022).

In many regions in Ghana where cashew fruits thrive, the pseudo apple fruit, which constitutes about 90% of the whole fruit as indicated in figure 1, is underutilized. This is primarily due to the fruit's astringent nature caused by its high tannin content and its perishability. Additionally, one of the main reasons people refrain from consuming cashew fruit is the prevalent myth surrounding its safety and potential harm to human health (Akyereko *et al.*, 2022). This article seeks to debunk the misconceptions associated with cashew apples, providing an understanding of their true nature and addressing the beliefs that have instilled fear and uncertainty in some individuals.

The Myth

The prevailing myth suggests that cashew apples are poisonous and is a threat to human life when consumed. This misconception is rooted in historical superstitions aimed at protecting the valuable cashew nuts from theft. Additionally, concerns have been raised about consuming cashew apples with milk or sugar, and fears of microbial contamination have further contributed to the myth (Akyereko *et al.*, 2022).

Debunking the Myth

1. **Superstitious Beliefs and Protection of Cashew Nuts:**
   The belief that cashew apples are poisonous was likely created in the past as a means to safeguard the valuable cashew nuts. By creating a perception of toxicity in the fruit, it acted as a deterrent for potential thieves (Akyereko *et al.*, 2022). It is crucial to highlight that these beliefs were rooted in superstitions rather than being supported by scientific evidence.

2. **Consumption with Milk or Sugar**:
   According to one aspect of the myth, it is believed that the consumption of cashew apples with milk or sugar can potentially lead to fatal consequences. This notion stems from the presence of tannins, which are naturally occurring compounds found in various fruits and plants, including cashew apples. When combined with milk, tannins can cause milk proteins to coagulate, forming curds. However, this coagulation is a natural process and does not pose any significant health risks. (Poornakala *et al.*, 2020) Consuming cashew apples with milk or sugar, therefore, does not lead to fatality or harm.
   In an investigation carried out by Dedehou *et al.* (2016), a study was conducted to explore the potential toxicity associated with the simultaneous consumption of cashew apple juice and milk. The purpose was to determine whether the belief that consuming cashew apple juice with milk could be fatal had any scientific basis. The study results demonstrated the absence of toxicity when mice were given a combination of cashew apple juice and milk. Additionally, the researchers observed a positive effect in the production of red blood cells, in the mice following the consumption of the mixture. Based on these findings, the authors concluded that there was no evidence of toxicity in the mixture when tested on mice, suggesting that it is also safe for human consumption. (Adou *et al.*, 2013) The study's results challenge the notion that the consumption of cashew apple juice with milk can be lethal.

3. **Lack of Empirical Data or Evidence of cashew Apples Toxicity:**
   The belief that cashew apples are toxic or lethal is not supported by empirical data or scientific studies. Research conducted by Sousa *et al.* (2021) has shown that extracts obtained from cashew apples demonstrate non-toxicity in zebrafish and human tumor cells. The findings of this study offer proof that cashew apples can be consumed safely without posing any risks to human health.

4. **Nutritional Value, Culinary Uses and Medicinal purposes:**
   The cashew apple contains a variety of beneficial nutrients such as vitamins, fructose, glucose, minerals, amino acids, phenolics, organic acids, antioxidants, and carotenoids which confers health benefits as indicated in figure 2. It is also recognized as an excellent energy source (Oliveira *et al.*, 2002; Campos *et al.*, 2002; Trevisan *et al.*, 2006). In regions where cashew apples are consumed, they are often used to make juices, jams, chutneys, and even alcoholic beverages (Dedehou *et al.*, 2015). These culinary uses highlight the versatility and safety of cashew apples as a food source. Cashew apple extract exhibits strong inhibitory activity against tested organisms, particularly Salmonella typhimurium. According to Laxmanaswami and Urooj (2018), the phytochemical analysis verified the existence of phenolic compounds, flavonoids, and tannins in cashew apples. These finding lends credence to the long-standing traditional usage of cashew apples in the treatment of bacterial infections.

***Figure 2**: Nutritional Benefits of Cashew Apple (Fruitsinfo,2023)*

Conclusion

The myth surrounding the safety of cashew apples has been perpetuated by superstitious beliefs and unfounded fears. The notion that cashew apples are poisonous or lethal lacks empirical evidence and scientific support. Cashew apples are safe for consumption, and their nutritional value and medicinal purposes makes them a valuable component of various culinary preparations. It is crucial to dispel this myth and promote accurate information about the safety and benefits of cashew apples to ensure their rightful place in the diet and culinary traditions of communities where they are grown.

Acknowledgement

We express our gratitude to Prof. Ibok N. Oduro for reviewing this article, Prof. Faustina Wireko-Manu for her guidance, and Prof. Jacob Agbenorhevi for his consideration. We would also like to acknowledge the Ghana Science Association (GSA) for providing us with this opportunity.

Reference

Adou, M., Tetchi, F.A., Kouadio, J.A. and Amani, N.G., 2013. Preliminary study of in vivo toxicity of

mixture" cashew apple juice-milk" on mice. *Int. J. Pharm. Pharm. Sci. Res*, *3*(1), pp.41-47.

Akinwale, T.O., 2000. Cashew apple juice: its use in fortifying the nutritional quality of some tropical fruits. *European food research and technology*, *211*, pp.205-207.

Akyereko, Y.G., Wireko-Manu, F.D., Alemawor, F. and Adzanyo, M., 2022. Cashew apples in ghana: Stakeholders' knowledge, perception, and utilization. *International Journal of Food Science*, *2022*.

Campos, D.C.P., Santos, A.S., Wolkoff, D.B., Matta, V.M., Cabral, L.M.C. and Couri, S., 2002. Cashew apple juice stabilization by microfiltration. *Desalination*, *148*(1-3), pp.61-65.

Dedehou, E.S., Dossou, J., Ahohuendo, B., Saidou, A., Ahanchede, A. and Soumanou, M.M., 2015. Optimization of cashew (Anacardium occidentale L.) apple juice's clarification process by using cassava and rice starch. *Journal of Applied Biosciences*, *95*, pp.8989-9002.

Dedehou, E., Dossou, J., Anihouvi, V. and Soumanou, M.M., 2016. A review of cashew (Anacardiumoccidentale L.) apple: Effects of processing techniques, properties and quality of juice. *African Journal of Biotechnology*, *15*(47), pp.2637-2648.

Fruitsinfo, 2023. Description of cashew apples. *Digital photo*, accesed 02/06/2023,23:30GMT https://www.fruitsinfo.com/cashew-apple-fruit.php

Kimmyfarm,2021. What Happen with The Cashew Fruits When The Nut Harvested? *Digital photo* accessed 02/07/2023, 23:20GMT https://kimmyfarm.com/en/what-happen-with-the-cashew-apple-when-the-nut-harvested

Laxmanaswami, B. and Urooj, A., 2018. Phytochemical profile and antimicrobial activity of cashew apple (Anacardium occidentale L.) extract. *GSC Biological and Pharmaceutical Sciences*, *5*(3), pp.095-098.

OLIVEIRA, M.E.B.D., OLIVEIRA, G.S.F.D., Maia, G.A., Moreira, R.D.A. and Monteiro, A.C.D.O., 2002. Aminoácidos livres majoritários no suco de caju: variação ao longo da safra. *Revista Brasileira de Fruticultura*, *24*, pp.133-137.

Poornakala, S.J., Indumathi, V.M. and Shanthi, K., 2020. Value addition in cashew apple: a review. *International Journal of Chemical Studies*, *8*(6), pp.819-825.

Sousa, J.M.S., de Abreu, F.A.P., Ruiz, A.L.T.G., da Silva, G.G., Machado, S.L., Garcia, C.P.G., Filho, F.O., Wurlitzer, N.J., de Figueiredo, E.A.T., Magalhães, F.E.A. and Muniz, C.R., 2021. Cashew apple (Anacardium occidentale L.) extract from a by-product of juice processing: assessment of its toxicity, antiproliferative and antimicrobial activities. *Journal of Food Science and Technology*, 58, pp.764-776.

Trevisan, M.T.S., Pfundstein, B., Haubner, R., Würtele, G., Spiegelhalder, B., Bartsch, H. and Owen, R.W., 2006. Characterization of alkyl phenols in cashew (Anacardium occidentale) products and assay of their antioxidant capacity. *Food and Chemical toxicology*, *44*(2), pp.188-197

RECIRCULATING AQUACULTURE SYSTEM (RAS) FOR FOOD AND NUTRITIONAL SECURITY IN DEVELOPING COUNTRIES

Ing. Dr. Shadrack Kwadwo Amponsah and Miss Helena Asare

***Institution**: CSIR-Crops Research Institute, Kumasi*

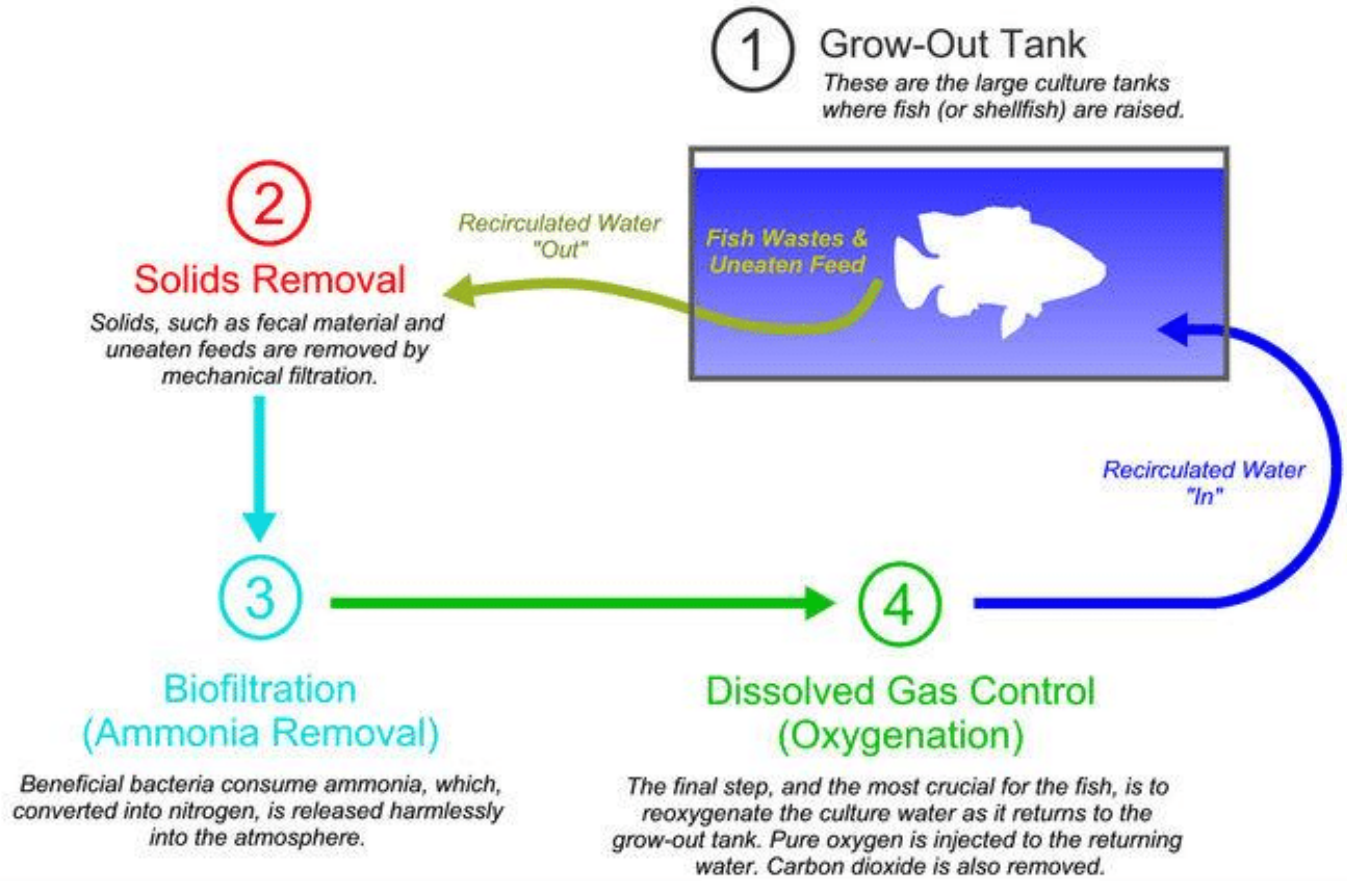


***Figure** 1: Simplified water treatment flow diagram of the RAS (Schmelmer, 2016)*

Introduction

With approximately 8 billion people on the planet, the demand for aquatic food is constantly increasing; thus, horizontal and vertical expansions of aquaculture production systems are highly recommended. According to the Food and Agriculture Organization (FAO), worldwide fishery output needs to increase by at least 50% to counter forecasted dietary protein shortages by 2030. Declining fish supply from capture fisheries is insufficient to provide cheap protein for the growing population. Natural water bodies face several issues, ranging from pollution caused by mining to low water levels that jeopardize fisheries. Aquaculture has existed for centuries, predominantly utilizing earthen pond and floating cage systems. At an annual rate of 6%, aquaculture is the fastest-growing food production sector in the world and already produces more than half of the fish eaten in the world today (FAO, 2020; FAO, 2022).

Over the past four decades, recirculating aquaculture systems (RAS) have evolved to become an increasingly viable option for a variety of species and life stages. In 1940, Denmark was one of the first countries in the world to implement RAS technology for the purpose of commercial European eel aquaculture (Espinal & Matulić, 2019). Research on RAS began in earnest in Japan in the 1950s, with scientists there focusing on biofilter design for carp production to make better use of scarce local water supplies. In different parts of the world, recirculating aquaculture systems are now used to raise freshwater and saltwater species like rainbow trout, salmon, prawns, tilapia, and catfish. Collaborative research efforts in 2014 between the CSIR-Crops Research Institute and Embrapa Mid-North led to the first successful implementation of the innovative RAS system of tilapia culture in Ghana (Amponsah, 2018). Since then, the RAS has been successfully adopted for catfish rearing across different regions of Ghana, led by Wontesty Ventures, a Ghanaian agribusiness that specializes in the local adaptation of RAS. Sustainable system intensification requires more environmentally responsible management. Recirculating aquaculture systems (RAS) are

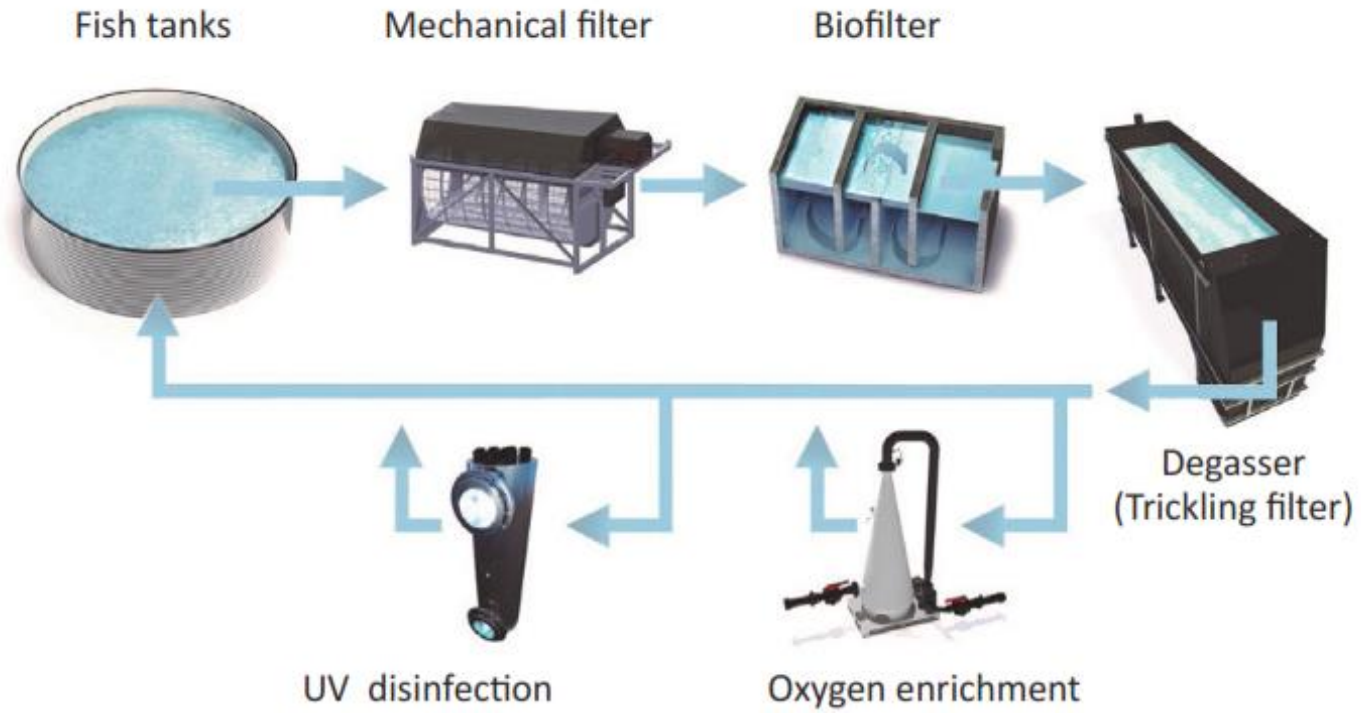


Figure 2: *High tech RAS design with UV disinfection (Bregnballe, 2022)*

intensive fish production systems that use a series of water treatment steps to purify and reuse fish-rearing water. The impact of waste products from extensive and semi-intensive aquaculture systems on the ecosystem, particularly cage culture aquaculture methods in rivers, ponds, and oceans, has drawn significant public attention (Sanchez *et al.*, 2016). Thus, the RAS might offer a sustainable option to alleviate the environmental impact associated with semi-intensive and extensive aquaculture systems such as the cage and pond culture. In addition, the RAS technology could directly contribute to achieving SDGs 2 and 6 of zero hunger and clean water and sanitation, respectively.

Undoubtedly, RAS technology presents enormous potential that could revolutionize and positively impact the aquaculture industry. Unfortunately, there is a considerable lack of information, and this is especially true in developing nations. It may be helpful to break the ice by gaining an understanding of the design and operation principles underlying the RAS in order to stimulate an appetite for additional research into this innovative production system.

What is RAS?

The term "recirculating aquaculture system", also known as RAS for short, refers to an intensive tank-based fish farming system or method that makes use of biofiltration and water exchange in order to reduce the amount of fresh water that is required while also preserving a healthy environment for the fish. In this method, fish are raised in environments that are subjected to a high level of environmental control. Recirculating aquaculture systems are utilised in home aquariums as well as in commercial fish production facilities. Ebeling & Timmons (2012) reiterate that these facilities have restricted water exchange and require the use of biofiltration to mitigate the toxic effects of ammonia. Through the use of mechanical and biological filters, RAS technology recycles water to remove organic waste (biosolids) and keep it in suitable condition to support fish growth and development.

RAS Design and Operating Principles

Fishponds and cages have not changed much over the years and are fairly uniform in design. Recirculating aquaculture systems (RAS), on the other hand, are diverse and are constantly changing, with new technology developed around the world. The RAS design incorporates several fundamental processes, the most important of which are mechanical filtration, biological filtration, oxygenation (aeration), and recirculation of the water. The RAS (Figure 1) will typically include devices to remove solid particles from the water which are composed of fish faeces, uneaten feed and bacterial flocs, nitrifying biofilters to oxidize ammonia excreted by fish to nitrate and a number of gas exchange devices to remove dissolved carbon dioxide expelled by the fish as well as/or adding oxygen required by the fish and nitrifying bacteria.

Some high-tech RAS designs (Figure 2) may adopt UV irradiation for water disinfection, ozonation and protein skimming for fine solids and

microbial control and denitrification systems to remove nitrate.

Mechanical filtration

Recirculating aquaculture systems (RAS) rely on mechanical filtration to rid the water of materials like sediment and suspended solids. Solid wastes in the RAS are typically derived from feeds that contain organic matter with a low density and a wide range of particle sizes (Tawfik *et al.*, 2023). If suspended solids are not removed, they can severely damage fish gills (Kjelland *et al.*, 2015), resulting in high fish mortality and reducing the number of fish that can be grown in the system. Additionally, the presence of suspended solids in culture tanks can potentially harm fish health by feeding and sheltering bacteria that deplete the tanks' precious oxygen reserves.

Biological filtration

Biofiltration is an essential step in the RAS water treatment process. Ammonia is created as a waste product as fish break down the protein in their meal. Unionized ammonia is extremely poisonous to fish, the percentage of which is influenced by temperature and pH (Francis-Floyd *et al.*, 2022). Tryggvason (2016) reiterates that one of the main issues in aquaculture is ammonia buildup. The biological filtration stage is important because not all the organic matter is removed in the mechanical filter. Usually, the finest particles will pass through together with dissolved compounds such as phosphate and nitrogen. Phosphate is an inert substance, and it does not have any toxic effects whatsoever. On the other hand, nitrogen in the form of free ammonia (NH_3) is toxic, and it must be transformed into harmless nitrate by the biofilter. Biofiltration is the method utilised by all RAS in order to convert the ammonia (NH_4^+ and NH_3) that is expelled by the fish into nitrate. Ammonia is oxidized in biofilters by communities of nitrifying bacteria that include species of the genera *Nitrosomonas*, *Nitrosococcus*, *Nitrospira*, *Nitrobacter* and *Nitrococcus* (Espinal & Matulić, 2019).

Biofilters used in recirculation systems can be designed as fixed bed filters or moving bed filters. In order for the biofilter to perform its function properly, it must be constructed in such a way that the nitrifying bacteria have adequate substrates to attach themselves to and sufficient space in which to reproduce. This is the rule of thumb that must be followed irrespective of the type of bed filter adopted. Different media that can be used in the design of RAS biofilter include sand, gravel, biological sponge and plastic beads.

Aeration

Aeration of the water results in the release of CO_2 and the subsequent degassing of the water. The process of aeration is accomplished with the assistance of specialised submersible pumps, which help to add some oxygen to the water through simple exchange between the gases that are present in the water and the gases that are present in the air. The amount of oxygen that is added to the water is usually proportional to the saturation level of the oxygen that is present in the water. The pump oxygenates, circulates, and properly distributes the pond's life-giving water. The role of the pump system is to provide enough pressure to overcome the operating system pressure in order to move fluids at the required flow rate. An electrical component of the pump spins an impeller, which generates centrifugal force to force the water to flow. A centrifuge spins an object in a circle around a fixed axis. The force applied will be at 90° to the axis of spin, resulting in a principle known as the centrifugation principle. The centrifuge system reduces waste volume by spinning sludge to separate solids and liquids, with suspended particles gathered at the center of the pond by the pump. This explains why most RAS tanks have circular geometry. According to the findings of a study conducted by Amponsah et al. (2021), which evaluated the effect of tank geometry on catfish production, circular tank geometry was found to be the most effective at managing biosolids in RAS. Bregnballe (2022) affirms that a circular tank geometry is superior in terms of its self-cleaning effect, low residence time of particles, oxygen control, and regulation in RAS, despite the fact that it has poor space utilisation.

Water recirculation

Purified water is returned to the fish tank to create circulation as part of the biological treatment process, which transforms toxic ammonia into a harmless nitrate in the biofilter. The circulation of water mixes the water column, which disrupts the ability of cyanobacteria to migrate vertically while also limiting nutrient accessibility (Khatib et al, 2019). Water circulation also prevents water column stratification and supplies available oxygen into the RAS to avoid oxygen deficits.

In the RAS, water quality parameters including Dissolved Oxygen (mg/L), Conductivity, Total dissolved solids, Salinity, pH and Temperature are well controlled in the system to maintain a good water quality to support fish growth and development. In intensive aquatic systems like the RAS, dissolved oxygen (DO) is typically considered to be the most important water quality parameter. This is due to the fact that low DO levels can quickly result in high levels of stress in fish, malfunctioning nitrifying biofilters,

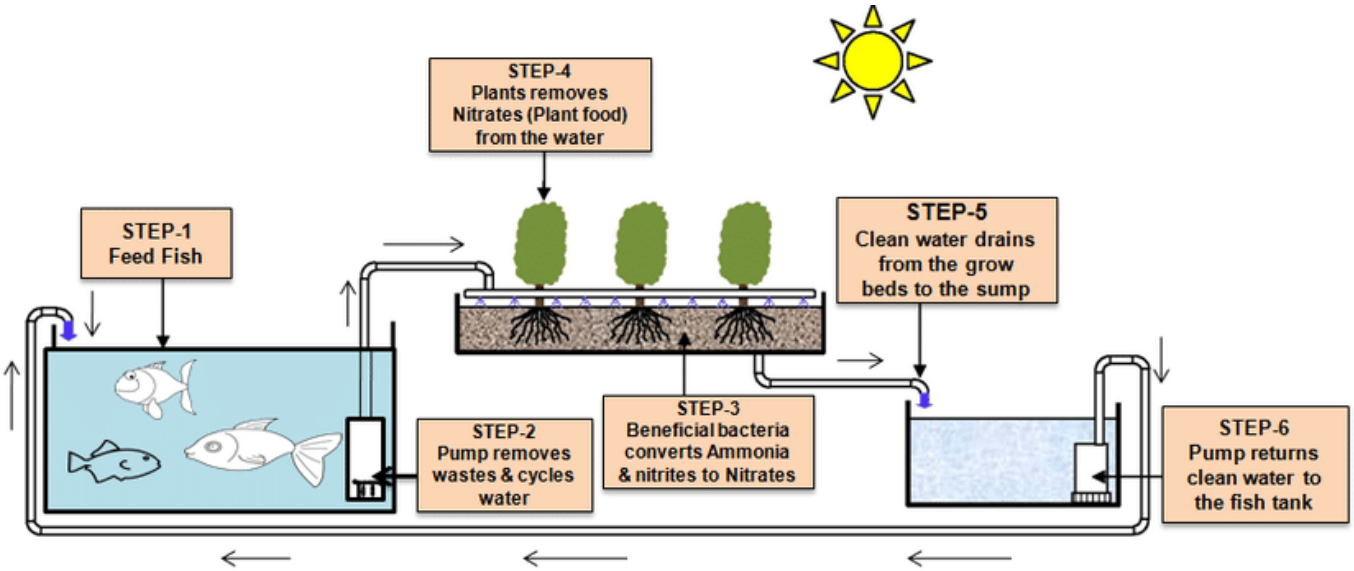


Figure 3: *Schematic illustration of an aquaponics system (Jena et al., 2017)*

and significant fish losses (Espinal & Matulić, 2019).

Benefits of the RAS

Recirculating aquaculture systems (RAS) have several benefits. They are designed to minimize environmental perturbation by reducing nutrient pollution discharge. In a recirculating aquaculture system, pathogenic infestations are considerably reduced due to the minimal spread of invasive illnesses from the outside environment. Thus, RAS can also reduce the risk of disease transmission and improve overall fish health. Additionally, RAS can be used to produce fish in areas where water is scarce or of poor quality. The capacity to reuse roughly 90% of the water in a closed system through several treatment loops is one of RASs' main benefits over conventional aquaculture systems. When compared to conventional tank culture systems, recirculating aquaculture system (RAS) technology replaces 10% of total volume daily to remove major toxic pollutants with minimal environmental impact, resulting in significant water savings (Twarowska *et al.*, 1997). Recirculation aquaculture systems (RAS) are promoted as innovations in the food sector that will significantly contribute to a more sustainable development (Meisch & Stark, 2019). RAS technology can raise fish in any climate and near population centres and markets, making it the most adaptable aquaculture production system.

Problems with the RAS

The downsides of the RAS include high initial costs and high risks due to high stocking densities. High operating costs are mostly due to electricity, and system maintenance. RAS systems have also been associated with high greenhouse gas emissions (Tilman & Clark, 2014). The need for highly trained staff to manage the systems has also been cited. Perhaps, these and other operational factors have contributed to the low adoption of RAS in most developing countries.

RAS and Aquaponics

Aquaponic systems are a subset of recirculating aquaculture technology in which crop plants are grown either to diversify a business's production or to provide additional water filtration capacity, or both (Espinal & Matulić, 2019). RAS can be further improved by combining them with aquaponics, where fish produce waste that fertilizes plants, creating a closed loop system. Combining plants and fish in a RAS is referred to as aquaponics as illustrated in Figure 3. In this type of system ammonia produced by the fish is not only converted to nitrate but is also removed by the plants from the water (Diver, 2006). In an aquaponics system fish effectively fertilize the plants, this creates a closed looped system where very little waste is generated and inputs are minimized. Aquaponics provides the advantage of being able to harvest and sell multiple crops. In developing countries, particularly in Africa, where water and land resources are limited and where climate change poses a risk, the use of aquaponics has the potential to increase food and nutritional security.

Harnessing the Potential of RAS: The Ghanaian Case Study

Ghana's aquaculture sector contributes nearly 5% to GDP and employs approximately 10% of the population (Statista, 2021). Ghana's declining fish supply from capture fisheries is insufficient to provide cheap protein for the growing population, owing to the country's ever-growing population and rising food insecurity. Ghana is about 60% short in fish production, with an annual fish import bill of $311 million (USDA, 2019; Damalie, 2021). According to the Ministry of

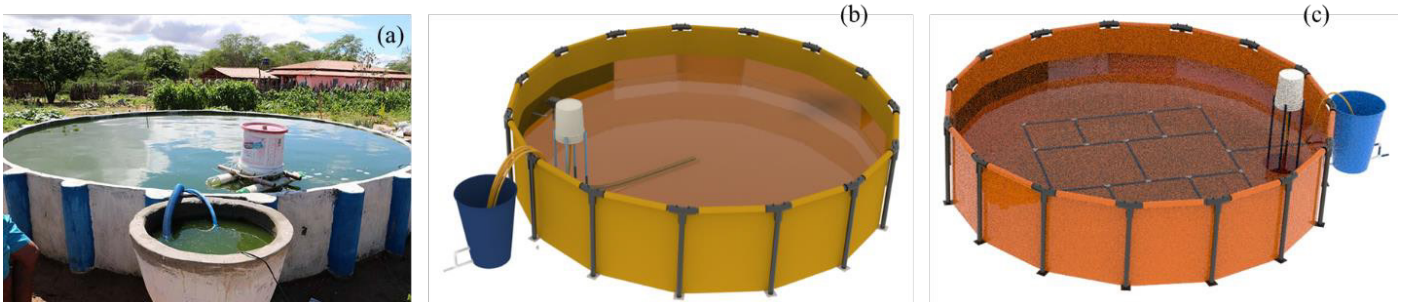


Figure 4: *The evolution of the RAS design*
(a) Initial Brazilian RAS on a concrete tank in 2014 (b) Adapted RAS design on a mobile tarpaulin tank in 2019
(c) An improved RAS design with PVC suction mat installed on a mobile tarpaulin tank (2021 – date)

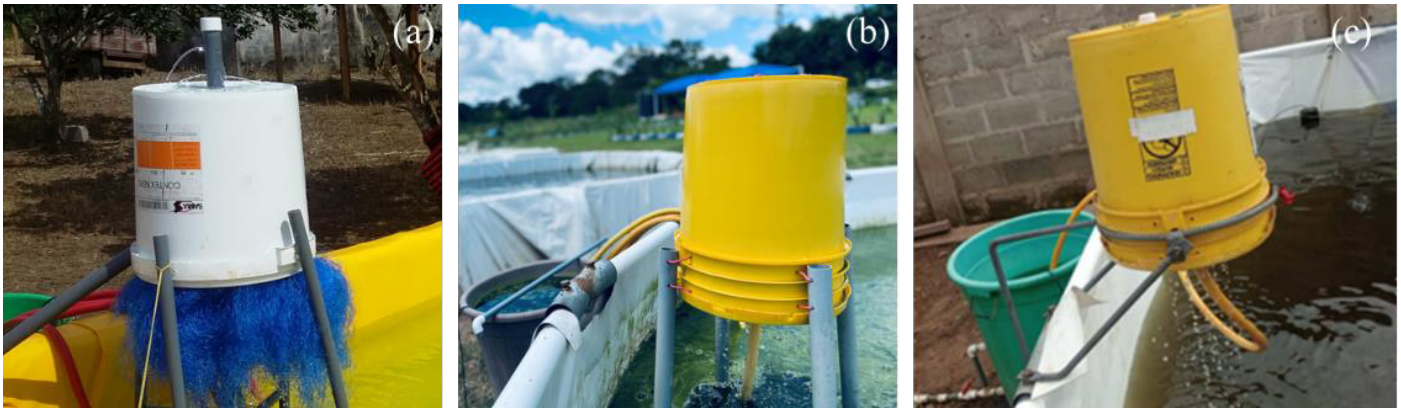


Figure 5: *Local adaptation of the biological filter*
(a) initial design in 2014 (b) 2019 design and (c) improved design in 2022

Fisheries and Aquaculture Development (MoFAD) report, the country's inland aquaculture is able to meet only 13% of the total annual fish demand. There are a variety of production or holding systems available, some examples of which include concrete tanks, earthen ponds, and floating cages. Cage culture is responsible for producing the vast majority of farmed tilapia, while ponds and tanks are responsible for producing the rest. Tank culture systems, albeit in the minority, have the potential to transform the narrative in Ghana's aquaculture sector if properly harnessed.

Since the partnership with Embrapa in 2014, which led to the first known introduction of RAS into the country, a Ghanaian Agricultural Engineering Researcher has taken the adaptation and promotion of the RAS to an entirely new level. Employing locally accessible materials and know-how, the initial RAS design has evolved into an effective recirculation system that enables users to cultivate freshwater species such as the African catfish (*Clarias gariepinus*) and the Nile tilapia (*Oreochromis niloticus*). Aspects of the RAS adaptation process from the initial Brazilian design are illustrated in Figure 4.

The two Ghanaian RAS adaptations (Figure 1(b) and (c)) and their Brazilian counterpart differ in the suspension of the biological filter and the material utilised for the waste collection tank. Figure 1(b) uses a set of water hoses to bring water into the waste bucket from the top of the tank, whereas Figure 1(c) uses a set of PVC suction mats via capillary action from the bottom to achieve the same result.

Figure 5 illustrates how the biological filter has changed over time, beginning with its first design in 2014. After it was discovered that the biofilter stand accumulated a significant amount of biosolids, affecting water quality, the design in Figure 5(c) was developed as an upgrade from Figure 5(b). This confirms the demand-driven approach to the entire evolution process of the locally adapted RAS.

The locally adapted RAS can effectively cultivate 1000 pieces of African Catfish juveniles (≥10g) to an average of 1kg weight in 4-6 months using approximately 500 kg of fish feed. Fish tanks can be permanently installed or mobile and customized to any size. They can be made out of wood, cement blocks, or tarpaulin canvas, and they can have a variety of shapes (circular, rectangular, and ellipsoid). The RAS design is energy efficient as it requires only 100 Watts of electricity power to run two submersible pumps used for aerating and recirculating the pond water.
This local adaptation and research approach on the RAS has led to the creation of an agribusiness which

specializes in the construction of RAS fishponds, with the vision to pond every household in Ghana by 2040. From 2017 to date, Wontesty Ventures has installed over 380 RAS fishponds across the country with over 90 direct and indirect users of the locally adapted RAS technology. The fish value addition campaign started by Wontesty Ventures in 2018 has also helped this move create a big market in Ghana, especially for African Catfish. As a result, numerous "point and grill" restaurants have sprung up in major towns and cities, providing income and food for a significant portion of the population, particularly the young and elderly. These restaurants are directly reliant on aquapreneurs utilising the RAS fishponds, making aquaculture production in Ghana quite profitable despite the skyrocketing fish feed price increases.

Conclusion

Ghana and, by extension, other countries in sub-Saharan Africa have favourable conditions to encourage the development and widespread use of the RAS as a viable aquaculture production system. The challenges faced by the aquaculture industry present a significant opportunity to develop new perspectives and contribute to a new narrative. Food and nutritional security are issues that must be prioritised for developing countries in light of the fact that new pandemics like COVID-19 are on the horizon. Therefore, it is expedient to look inward and leverage the appropriate technology to revolutionise the country's aquaculture sector for significant impact. Under these conditions, it is worthwhile to promote the locally adapted RAS because it makes it possible to produce fish at any time of the year and can be carried out anywhere with the resources that are readily available locally. This is a call to action for researchers in the area of Agricultural Engineering and related fields to develop demand-driven, industry-specific solutions for the aquaculture sector with a focus on developing countries.

References

Amponsah, S. K. (2018). *Yali Voices: Making Aquaculture Possible With Simple Fish Tanks*. Young African Leaders Initiative (YALI) Network. https://yali.state.gov/yali-voices-making-aquaculture-possible-using-simple-raised-fish-tanks/

Amponsah, S. K., Agodzo, S., Agbeko, E., & Osei, E. A. (2021). Impact of tank geometry on production of African Catfish (Clarias gariepinus). *African Journal of Agricultural Research*, *17*(1), 165–172.

Bregnballe, J. (2022). *A Guide to Recirculation Aquaculture: An Introduction to the New Environmentally Friendly and Highly Productive Closed Fish Farming Systems*. Food and Agriculture Organization of the United Nations. https://books.google.com.gh/books?id=jXsIkAEACAAJ

Damalie, P. E. (2021). $150m Spent on fish imports yearly - Ghana Tuna Association. *Graphic Online*. https://www.graphic.com.gh/news/general-news/150m-spent-on-fish-imports-yearly-ghana-tuna-association.html

Diver, S. (2006). Aquaponics-Integration of Hydroponics with Aquaculture. In *ATTRA-National Sustainable Agriculture Information Service*. www.attra.ncat.org

Ebeling, J. M., & Timmons, M. B. (2012). Recirculating aquaculture systems. In *Aquaculture production systems*, (Vol. 1, pp. 245-277.).

Espinal, C. A., & Matulić, D. (2019). *Recirculating Aquaculture Technologies BT - Aquaponics Food Production Systems: Combined Aquaculture and Hydroponic Production Technologies for the Future* (S. Goddek, A. Joyce, B. Kotzen, & G. M. Burnell (eds.); pp. 35–76). Springer International Publishing. https://doi.org/10.1007/978-3-030-15943-6_3

FAO. (2020). The State of World Fisheries and Aquaculture 2020. In *Sustainability in action*. https://doi.org/10.4060/ca9229en

FAO. (2022). The State of World Fisheries and Aquaculture 2022. In *Towards Blue Transformation*. Food and Agriculture Organisation of the United Nations. https://doi.org/10.4060/cc0461en

Francis-Floyd, R., Watson, C., Petty, D., & Pouder, D. (2022). Ammonia in Aquatic Systems. *EDIS*, *2022*(4). https://doi.org/10.32473/EDIS-FA031-2022

Jena, A. K., Biswas, P., & Saha, H. (2017). Advanced Farming Systems in Aquaculture: Strategies To Enhance the Production. *Innovative Farming*, *1*(1), 84–89. https://www.researchgate.net/publication/316191741_ADVANCED_FARMING_SYSTEMS_IN_AQUACULTURE_STRATEGIES_TO_ENHANCE_THE_PRODUCTION

Kjelland, M. E., Woodley, C. M., Swannack, T. M., & Smith, D. L. (2015). A review of the potential effects of suspended sediment on fishes: potential dredging-related physiological, behavioral, and transgenerational implications. *Environment Systems and Decisions*, *35*(3), 334–350. https://doi.org/10.1007/s10669-015-9557-2

Meisch, S., & Stark, M. (2019). Recirculation Aquaculture Systems: Sustainable Innovations in Organic Food Production? *Food Ethics*, *4*(1), 67–84.

https://doi.org/10.1007/s41055-019-00054-4

Schmelmer, K. (2016). *The combination of aquaponics systems and grey-water recycling - Introduction of the Greyponic system-* [Tongji University Shanghai]. https://doi.org/10.13140/RG.2.2.18190.36161

Statista. (2021). *Ghana: annual fish production by source*. https://www.statista.com/statistics/1278935/annual-fish-production-in-ghana-by-source/

Tawfik, M. A., Salem, M. A., & Zaki, R. I. (2023). Performance investigation of a novel design of vertical micro-screen drum filter for a recirculating aquaculture system (RAS). *Aquaculture International*. https://doi.org/10.1007/s10499-023-01085-9

Tilman, D., & Clark, M. (2014). Global diets link environmental sustainability and human health. *Nature*, *515*(7528), 518–522. https://doi.org/10.1038/nature13959

Tryggvason, Á. Þ. (2016). *A Systematic View on a Recirculating Aquaculture System: Causality Relation Between Variables*. University of Iceland.

Twarowska, J. G., Westerman, P. W., & Losordo, T. M. (1997). Water treatment and waste characterization evaluation of an intensive recirculating fish production system. *Aquacultural Engineering*, *16*(3), 133–147. https://doi.org/https://doi.org/10.1016/S0144-8609(96)01022-9

USDA. (2019). *Ghana: Fish and Seafood Report*. Foreign Agriculture Services. https://www.fas.usda.gov/data/ghana-fish-and-seafood-report

WHAT'S ON YOUR PLATE? THE STORY OF FOOD SECURITY

Etornam C. Tsyawo (BSc), Ibok N. Oduro (PhD)
Institution: *Department of Food Science and Technology, KNUST*
Email: *ectsyawo@gmail.com*

Figure 1: *a popular Ghanaian dish, waakye with salad (credit: Etornam C. Tsyawo)*

Introduction

What would you be having for breakfast tomorrow morning? Maybe 'waakye with salad' like the one you see in figure 1? You probably do not think too much about where this food or the ingredients used to make it come from, do you? Do you know that some people in your neighborhood and even all over the world do not have enough food to eat? Or that some of the food they eat is not healthy? And sometimes too, people do not even have a choice of what to eat? This is what happens when people don't have food security. When there is food security, all people including you, have enough safe and nutritious food that meet your diet and your choices. In this article, you will learn more about what food security is, why it is important, and what you can do to improve it.

What is food security?

Food security is having access to enough safe and nutritious food that meets your dietary needs and preferences for a healthy life (FAO, 2023). For you and everyone else to be truly food secure, four areas need to be present and work together (World Bank, 2023). These four areas are known as the dimensions of food security. They are;

1. availability
2. access
3. utilization
4. stability

As you can see in figure 2 below, each dimension the dimensions feed into one another. Let's take a closer look at each of them.

Figure 2: *the dimensions of food security (credit: Etornam C. Tsyawo)*

Availability: this means that **there is food of good quality** for us all. This food is mainly produced by farmers, both large commercial farmers and smallholder farmers. After production, the food is then stored in various places such as warehouses, supermarkets, among others. So that, whenever you need food, it would be there for you. But sometimes, certain situations can reduce the availability of food. For instance, bad weather situations such as drought can cause crops to die in the field. Pests like weevils can destroy food during storage. Diseases can also affect crops in the field and during storage, as well as animals, thereby making them unsuitable for eating. All these and other situations spoil food and make it less available for us. Can you think of any other situation that can cause food to be less available?

Access: this means we **have enough money and resources** to get the food we need and want. Have you ever wanted to buy some particular food but did not have the money, so you bought another food instead? Or some other time too, the food was just expensive? If yes, then your access to food was limited. Aside money, we require shops and markets to buy or sell food. Without any point of sale, it would be difficult for us to have access to food. We also need a means of transport in order to get access to food. The 'waakye' you plan to take for breakfast tomorrow morning, the rice, beans and other ingredients were transported from a farm or other production points to a market before Hajia was able to go and buy it to prepare the 'waakye'. Without transport, it would have been more difficult accessing the ingredients. There are some circumstances that can reduce our access to food. For instance, low income. Without money, you cannot buy food. Distance is another factor. Have you eaten fresh strawberries before? Maybe yes, maybe not. Strawberries are not typically grown in Ghana. And even if you ate some before, it is very likely it was imported from another country, and this makes it very expensive. Conflicts can also reduce our access to food. When there is war in a country that produces most of the world's food, our access to that food would be reduced. Have you heard of the Russia-Ukraine war?

Utilization: this means we can use the food we have in a way that **benefits our health** and nutrition. For us to achieve this, our bodies need to be able to digest the food and absorb the nutrients appropriately. We need clean water like the one in figure 3 to prepare the food. We also need fuel to provide a heat source to cook the food. Another important thing we need is the knowledge on how to prepare and store the food safely.

Figure 3: *clean water is needed for better food utilization (credit: Canva)*

What is your favourite food? Do you know how to prepare it? Apart from these, we also need good health and nutrition to digest and absorb the nutrients from food. Occasionally, some situations prevent us from utilizing food appropriately. Illness is one of them. If you are not feeling well, you probably would not feel like eating. Or due to a certain illness, some people cannot eat some particular kinds of food. Another situation is pollution. You remember we mentioned clean water as a requirement for us to utilize food? What do you think happens if we don't have access to clean water? Our food would not be safe and when we eat it, we can fall sick. And this would further reduce how we utilize food.

Stability: means everyone **has and uses enough quality food** at al times. It also means that all the three dimensions already discussed above should be stable. Imagine that food is available, but you do not have the money to buy it (lack of access). Or you have the money but there is food shortage (low availability). Or even, the food is there and you have the money but the water running from your tap is impure (reduced utilization). In any of these situations, your food security status is unstable. And this is termed as food insecurity. When any of the dimensions is not met, we are faced with food insecurity. This is actually what the entire world is faced with currently and that is why we need to take action now.

Why is food security important?

Food security is important for many reasons.

- First of all, it is a basic human right that everyone deserves. We all have the right to adequate food that meets our needs and preferences. Without food security, we can suffer from hunger, malnutrition, and health problems. This can affect our growth and well-being. If our wellbeing is affected, we cannot live quality lives.
- Food security is important for health and well-being. This has a direct link with the first point. Food security can prevent or reduce many health problems, such as obesity, diabetes, and other infections. It can also improve our mental and emotional health, as well as our development and productivity. For instance, if you are well-nourished, you can perform

better at school and have better opportunities to pursue your dreams.

- Food security is important for sustainable development. Food security is related to many things that make the world a better place. For example, personal economic growth – when people have jobs, they can get enough money to buy food. Fair trade – when we do business honestly with one another, it can help us generate a diverse range of resources that would make us able to meet all the dimensions of food security. Good policies (rules) also matter – when the government and other leaders make good rules that promote growth, it can help us succeed in various areas, as well as our food security status.

Vocabulary

FACT
690 million people in the world are hungry!
(World Bank, 2023)

Sustainable development is a way of growing and improving our lives without harming the environment or future generations.

So, what can you do to improve food security?

There are many things that you can do to improve food security in your home, neighborhood and even the world. Here are some examples:

1. Reduce the amount of food you waste. You can do this in several ways. Dish the amount of food enough for you at a time, do not dish out too much and throw the rest away when you are filled. Store your food properly so it does not spoil. Handle the fresh produce you buy from the market well. For instance, do not just throw the fresh tomatoes you bought into the refrigerator. Instead, separate the soft from the hard ones. You can wash and steam the soft ones, and then freeze them. For the hard ones, you can keep them in your refrigerator. If you can, plan your meals ahead of time so you can eat what you really want provided you can afford it.
2. Eat a balanced diet that includes a variety of foods from the different food groups. This way, you can feed your body the right amounts of nutrients it needs. Also, drink enough water everyday. About 4 to 6 sachets or glasses of water is good (LeWine, 2023). Whenever possible, you can also try new foods that are nutritious and from different cultures. Are you always eating 'fufu' with goat light soup? Maybe you can try 'fante kenkey' with 'kontomire' stew or even 'sukuma wiki', a popular Kenyan dish!
3. Produce some of your food. Planting a garden can enable you have access to some fresh food at all times. For instance, you can have a small vegetable garden where you cultivate such as the one in figure 4 below. With this, you can harvest some fresh food from time to time to prepare your dishes. This increases the availability and access of food to you, your family and even your community.
4. Raise awareness about food security issues by learning more about them and sharing your knowledge with others. You just took a major step by reading this article. The next step is to practice some of the suggestions here in your day-to-day activities. Which would you want to start with? Maybe storing food properly or handling your fresh produce well? Then, you can also share what you've learned with your family, friends, and other people in your community.

What is next?

You have just discovered the amazing world of food security! You have learned what it means, why it matters, and what you do to make a difference. Food insecurity is a big challenge that affects everyone in the world. But it is also a perfect opportunity to create a better future for yourself, your community, and the entire world. You have the power to change things by taking small actions in your daily life. You can be a food hero. Are you ready to take action?

Figure 4: *lettuce garden (credit: Etornam C. Tsyawo)*

References

FAO. (2023). Food security and the right to food. FAO.org. http://www.fao.org/sustainable-development-goals/goals/goal-2/en/

LeWine, H. E. (2023). How much water should you drink? Harvard Health Publishing. https://www.health.harvard.edu/staying-healthy/how-much-water-should-you-drink

World Bank. (2023). Food security update: World Bank response to rising food insecurity. https://www.worldbank.org/en/topic/agriculture/brief/food-security-update-world-bank-response-to-rising-food-insecurity

World Bank. (2023). What is food security? Retrieved June 22, 2023, from https://www.worldbank.org/en/topic/agriculture/brief/what-is-food-security

COOKING AND LIGHTING WITH LANDFILL GAS; A CLEANER CITY WASTE TO ENERGY TECHNOLOGY

Dr. Kofi Ampomah-Benefo, Dr. Rapheal Nsiah-Gyambibi, Gloria Boafo-Mensah, Dr. Elizabeth Von-Kiti

Institution: *Consultant and Senior Research Scientist, Council for Scientific and Industrial Research, Ghana*
Email: *kabenefo@gmail.com* | ***Tel:*** *0244487648*

Waste from homes

Poor community

Poor waste management

Disposal of waste (landfill)

Overflow at landfill

Queuing at landfill

LFG extraction process

Gas pipe installation

In 2017 I published ***Black gold-organic waste can give energy***. I emphasized using the organic fraction of waste used to generate biogas, which is used for cooking. Large volumes of landfill (locally called ***borla***) generate gas, which can be tapped and used as a source of "clean" energy. This clean energy, commonly called landfill gas (LFG) can be used for electricity generation, which can be fed into the national electricity grid or used to generate heat for cooking and heating. In this publication I emphasize on the use of ***borla*** to generate energy and other benefits that may be obtained from the application of this technology.

Let us begin by looking at your response to the question; where does trash go when picked by waste collectors? When the ***borla car*** arrives, what kind of stuff does it carry away from your home? May be some pieces of broken plate, empty bottles, metal cans, kitchen leftover food, papers and not to mention all. All these are dumped in one container and the vehicle takes it away, moving from one house to the other till it is full. In some communities, people drop their waste along the road or in open drains such as the gutters by roads. Some of our communities are very filthy because we do not have proper waste management systems there. In some places where bins have been placed to receive waste from people passing by, it is a common practice for people to bring their waste and drop them in these small bins. The bins get full very quick and when not picked up before its scheduled time, the environment becomes messy. Probably we need some Avatars or supermen to manage our waste, where they can move as fast as the wind and clean our environment. If that is not possible then we all may need one form of education or the other to enable us transition from poor to excellent waste management.

In most cases, trash is finally sent to a landfill. Landfills are large, engineered sites where trash is buried (deposited). With time the landfill piles and becomes a huge mountain of plastics, metals, wood, bottles, rotten food, leaves, peels of foodstuff and other substances that are fermentable. Sometimes dead animals are carried among the trash and dumped at the landfill. The organic materials begin to decompose (ferment). At the surfaces and peripherals of the landfill, where O_2 is available aerobic decomposition takes place and the final products are CO_2, H_2O and some energy released in the form of heat. Deep inside the landfill where there is no O_2, it is obvious that the absence of O_2 leads to another kind of decomposition referred to as anaerobic. Anaerobic decomposition leads to the formation of CH_4, CO_2 and other traces of gases commonly referred to as biogas (landfill gas). CH_4 is combustible with an energy value of 3.725 MJ/m^3.

There are two main ways to get landfill gas:

1. **Active collection**: This involves drilling wells into the landfill and installing a system of pipes to

collect the gas. The gas is then pumped to a central processing facility where it is cleaned and prepared for use.

2. **Passive collection**: This involves installing a system of trenches or pits in the landfill to collect the gas. The gas rises to the surface and is collected through a series of pipes. The type of collection method that is used depends on the size and age of the landfill, the amount of gas that is produced, and the intended use for the gas. Once the landfill gas has been collected, it is typically cleaned and prepared for use. The cleaning process removes impurities such as water vapour, hydrogen sulphide, and siloxanes.

Offset firewood with LGC

Offset firewood with LGC

Transitioning from firewood

Clean cooking with LFG

As mentioned earlier, LFG is a source of clean fuel, which can be tapped and piped to kitchens, restaurants, hotels, hospitals, schools, etc. and used for cooking or electricity generation. It is therefore very appropriate to say ***there is wealth in trash (landfill)***. As part of national development and poverty alleviation programmes, organic waste right from homes, marketplaces, community centres, schools and event centres to the landfill must be cherished and properly treated. This could be the beginning of making poor people or communities rich. On a macro scale waste management in a country could be a big business and economic game changer for national development. This ideology is what makes organic waste black gold.

If organic waste gives energy, which can be used for cooking or electricity generation and poverty alleviation, why do we seem not to care about the waste we generate? Why some developing countries almost engulfed with filth (trash)? Why don't we plan and gather all organic waste in municipalities and harness the energy contained? It is hoped that with this exposure of waste to energy, we may get to the point where there will be zero waste in developing countries. Landfill gas generation technology is well-known and can be easily implemented. Benefits of using LFG for cooking include:

1. ***less dependent on wood fuel***: In the tropic, most of the developing countries use branches of trees and logs as firewood, which they get from the forest, the continues use of wood from the forest and not replanting leads to deforestation. There is a common saying that when the last tree dies the last man dies. This inadvertently means without growing more trees than we use, we may be ending humanity slowly.
2. ***healthy cooking environment***: Since firewood does not burn 'clean', traces of unhealthy gases are inhaled especially by women and children, who usually are in the cooking area and doing the cooking. Landfill gas used for cooking is less harmful because the combustion is complete and hence less harmful. When firewood is burned indoors, it produces smoke that can contain harmful pollutants, such as particulate matter (PM), carbon monoxide (CO), and nitrogen oxides (NOx). These pollutants can irritate the eyes, nose, and throat, and can also worsen respiratory conditions such as asthma and bronchitis. In severe cases, exposure to indoor air pollution from firewood burning can lead to death, and
3. ***improved energy security***: as long as we generate our own energy, we reduce the reliance on others to supply the energy for us. It also enables us to save money, which is an opportunity of wealth creation.

In conclusion, the organic component of waste that we let go off to the borla has energy, which can be tapped, either at home or at the landfill site to generate biogas. This means the gas we need from the organic waste can be generated at its source or its destination. Why do we have to pay money for the energy we can generate to go waste. ***It does not make sense to pay for energy to be disposed***. If we can generate some of the energy we need, then we will reduce our dependence on governments to

provide all the energy we need. We can reduce the amount of money we spend, for example to buy LPG if we generate our own gas. Our communities will become clean if we manage our waste well. The use of clean energy will reduce health challenges we face with the use of our traditional sources of fuels, such as firewood. Where does this change start; maybe from you and I. Lastly, let's change the landfill site to waste to-energy facilities. Let us apply what has been learned from this article. We have the solutions, so let us put them to use in our homes, schools, hospitals, prisons, farmlands, and municipalities. We are all available through our contacts provided. ***Let us make our cities clean by turning our waste into resources such as biogas generation for cooking, heating, and electricity generation.***

THE ROLE OF COUNSELLING IN SCIENCE EDUCATION

Rabbi Darko[1], Joan Soribang[2] and Ibok N. Oduro (PhD)[3]

Institution: *[1&2]Counselling Center, KNUST, [3]Department of Food Science and Technology, KNUST*

Email: *rabbi.darko@knust.edu.gh*

www.owlcation.com/social-sciences/Psychology-and-its-Importance

Introduction

We live in a time when dealing with people calls for strategic skills, personal competencies, knowledge of potential current circumstances and scenarios, guided tactics, etc. In this context, it should be noted that modern counselling is now essential for all professionals, including students. Counselling provides voluntary, confidential, situational issues for people of all ages and from all ethnic groups (Bedu-Addo, 2000). It is also a service created to aid an individual.

Science Education plays a vital role in shaping the feature of any nation, and effective counselling and support are instrumental in fostering a passion for scientific exploration among students (Kola, 2013). In this regard, the role of counselling in Science Education cannot be overstated. This article explores the impact of counselling on Science Education, with a particular focus on Africa, and more specifically, Ghana. Counselling in Science Education has the potential to unlock untapped potential, bridge educational gaps, and empower individuals to contribute to the advancement of their communities and the nation as a whole. Counselling in science education encompasses a wide range of activities, including academic advising, career guidance, and personal development support (Euroguidance Romania, 2018). Through these interventions, students receive tailored assistance in navigating their science education journey, enabling them to make informed decisions about their academic pursuits, discover their strengths and interests, and overcome challenges they may encounter along the way. Moreover, counselling in science education can help address the disparity in science enrolment and achievement among students in Africa, ultimately leading to more inclusive and equitable educational outcomes (Bauman et al., 2005).

In the context of Ghana, where a strong emphasis is being placed on developing Science and Technology sectors, counselling in science education holds significant promise. By leveraging the expertise of trained psychologists/counsellors, educational institutions can create a conducive environment that encourages students to explore science and pursue careers in STEM (Science, Technology, Engineering, and Mathematics) fields. Moreover, counselling can play a crucial role in encouraging female participation in

science education, which is essential in promoting gender equality and fostering innovation in Africa's scientific landscape. By providing guidance, support, and mentorship, counselling empowers students to unleash their potential, equipping them with the necessary skills and knowledge to thrive in science-related careers.

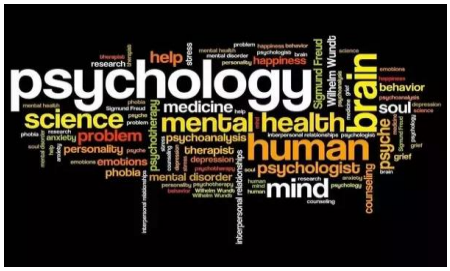
www.edumilestones.com/blog/details/The-role-of-career-counselling-in-economic-development

Current Trends

In recent years, the role of counselling has become increasingly important in shaping the science education system across the globe. Africa, including Ghana, is no exception. Even though some educational institutions have managed to employ the services of counselling in their practices, yet it appears the majority of them have not. One of the current trends in the role of counselling in science education is the integration of counselling services within the science curriculum. This approach aims to provide students with both academic and emotional support, helping them overcome challenges and develop a passion for science. By incorporating counselling into the science curriculum, students can receive guidance on subject selection, career paths, and overcoming obstacles that may hinder their success in science-related fields (Thamarasseri, 2014).

Importance of Counselling in Shaping Science Education

In today's rapidly changing world, counselling plays a vital role in science education, particularly in Ghana, and Africa at large. As students face various challenges and transitions, counselling provides essential support to help them overcome obstacles, make informed decisions, and reach their full potential by.



www.quora.com/What-is-the-role-of-psychology-in-education

Promoting Mental Health and Well-being: Counselling services in science education are crucial for promoting mental health and well-being among science students. In Ghana specifically, science students are mostly seen as extremely intelligent and excellent academic prowess is expected from them. These unrealistic expectations often than not open these young scientists up to unduly academic pressure, social anxiety, and personal issues that can impact their overall mental health. Counselling support services contribute to improved academic performance, self-confidence, and emotional resilience among science students.

www.ungcmyb.org/post/sustainable-development-goal-3-good-health-and-well-being

Addressing Academic and Career Guidance: Counselling in science education is instrumental in providing academic and career guidance (Amoah et al., 2015). Science as a subject has diverse branches and students within the discipline are likely to choose options that are not congruent with their interests and aspirations. Many students struggle with choosing the right educational path or career direction. Comprehensive counselling assists science students in identifying their strengths, interest, and future aspirations, offering guidance on suitable academic programs and career options. Such intervention helps science students make informed decisions about their future.

Enhancing Personal and Social Development: Since science education in Ghana is usually perceived as tedious, most science students spent most of their time studying and engaging in laboratory duties at the expense of enhancing their personal and social development. Counselling, therefore, comes in to plays a critical role in enhancing personal and social development among students. Through counselling sessions, science students aside from their main areas of specialities tend to learn other essential life skills, such as communication, conflict resolution, empathy, and cultural competence. These skills empower science students to build positive relationships, foster inclusive communities, and navigate the complexities of today's society (Bertelsen & UNESCO Internal Bureau of Education, 1978).

Support Special Needs and Inclusive Education: counselling within science education is essential for supporting science students with special needs and promoting inclusive education.

School psychologists/counsellors work closely with teachers and parents to identify science students with learning disabilities and assist in implementing appropriate interventions as well as contribute to creating inclusive classrooms that value diversity and ensure all students have equal access to quality education (Kahveci, 2016).

www.educerecentre.com/challenges-of-inclusive-education

Challenges

While counselling is an easily accessible service in many developed countries, its benefits are not yet adequately exploited in developing countries. Therefore, the many emerging issues that ought to have been addressed by an effective provision of counselling services in science education have continued to persist. These include poor academic performance, abandonment of science programmes and fear of science programmes, drug abuse, classroom discipline cases, and malpractices among others. These are indications that science students need counselling in the pursuit of their programmes. Some challenges in implementing counselling programs include:

- **Lack of funding:**
  Counselling programs need sufficient funding to enable them to put up infrastructure and purchase the necessary facilities. A conducive environment for counselling helps the counsellor to create a therapeutic environment which facilitates effective counselling. Lack of funding forces counsellors to undertake their duties without even the most basic amenities. This demotivates them from performing their basic roles and any duties assigned to them.
- **Non-cooperative instructors/students:**
  Most science students do not take counselling seriously and as a result hardly patronized the services. They usually focus on their studies and relegate the services of counselling to the rear jeopardizing their mental health. Due to their lack of confidence in the service, some of these science students are unwilling to discuss their issues and seek counselling from the counsellors. A negative attitude towards counselling on the part of some teachers/lecturers also contributes largely to this. It is surprising to know that in this contemporary era, there exist a considerable number of lecturers and teachers who do not see the essence of counselling and do not have the luxury of time to notice the struggles their students go through let alone refer them for counselling.
- **Inadequate facilities:**
  Quality counselling services within science education require facilities such as files, reference books, manuals, office space etc. Most science departments and faculties lack facilities and reference materials for use by counsellors to ensure effective counselling.
- **Inadequate time:**
  This has been the greatest challenge to the implementation of counselling in STEM/science education/s. Most science institutions do not make provision for counselling activities on their timetables. Counselling is usually relegated to the back and is normally perceived as the last resort. Counselling should be viewed as a crucial component of science education in order to help young scientists build their resilience to the difficulties they face on a daily basis.
- **Lack of parental support/religious differences:**
  It has been established that uncooperative parents act as an obstacle to the provision of counselling services in schools. Thus, some parents due to religious and cultural factors tend to discourage their children from sharing their private and domestic issues with outsiders. The support of parents and society at large is crucial for the success of counselling programs in science education because it is only through their participation will they understand the psycho-social problems of their children and participate in the formulation of solutions (Bertha, L., & Sadiq, S. A., 2020).
- Other challenges include a lack of support from the school administration, a heavy workload and a shortage of qualified personnel.

Conclusion and Recommendation

Counselling in science education is of utmost importance in Ghana and Africa as a whole. It addresses the unique challenges faced by science students, promotes mental health and well-being, provides academic career guidance, enhances personal and social development, and supports inclusive education. It is therefore recommended that various stakeholders should invest in comprehensive counselling services in science education. This will help educational institutions to empower science students to overcome obstacles, make informed decisions, and achieve their academic and personal goals. There is an urgent need for the training of professionally skilled and committed counsellors in science education. Again, basic psychology or introduction to psychology should be introduced in all science education curricula. This will enable

young scientists to appreciate the need to engage in counselling services in their pursuit of academic excellence. As Africa continues to advance and develop, counselling in science education remains a valuable resource in nurturing resilient and successful scientists who will contribute to the growth and progress of their communities and the continent as a whole.

References

Amoah, S. A., Kwofie, I., & Kwofie, F. A. A. (2015). The School Counsellor and Students' Career Choice in High School: The Assessor's Perspective in a Ghanaian Case. Journal of Education and Practice, 6(23), 57–65. https://ezp.lib.unimelb.edu.au/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=EJ1079015&site=eds-live&scope=site

Bauman, G. L., Bustillos, L. T., Bensimon, E. M., Ii, M. C. B., & Bartee, R. D. (2005). Achieving Equitable Educational Outcomes with All Students : The Institution's Roles and Responsibilities. Making Excellence Inclusive, 47.

Bedu-Addo, P.K.A. (2000). Guidance and Counselling 'unmasked'. (3rd Ed.). Accra. Type Company Limited.

Bertelsen, P. H., & UNESCO Internal Bureau of Education. (1978). Information, guidance and counselling. 8(2), 194–201. https://unesdoc.unesco.org/ark:/48223/pf0000028923

Bertha, L., & Sadiq, S. A. (2020). Challenges Facing Guidance and Counselling Coordinators in Senior High Schools in the Kumasi Metropolis in Ghana. International Conference on Applied Sciences and Technology (ICAST), 2016, 107–118. http://proceedings.kstu.edu.gh/index.php/icast/article/view/11/9

Boitt, M. L. J. (2016). Evaluation of the challenges in the implementation of the guidance and counselling programme in Baringo County Secondary Schools, Kenya. Journal of Education and Practice, 7(30), 27–34. http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=EJ1118929&site=ehost-live

Euroguidance Romania. (2018). Border Seminar Compendium. Cross Border Seminar Compendium, 138. www.euroguidance.eu

Kahveci, G. (2016). School Counseling and Students with Disabilities. International Online Journal of Primary Education, 5(2), 15–21. www.iojpe.org

Kola, A. J. (2013). Importance of Science Education to National Development and Problems Militating Against Its Development. American Journal of Education Research, 1(7), 225–229. https://doi.org/10.12691/education-1-7-2

Thamarasseri, I. (2014). Meta-Narrative on Guidance and Counselling. I-Manager's Journal on Educational Psychology, 7(3), 1–8.

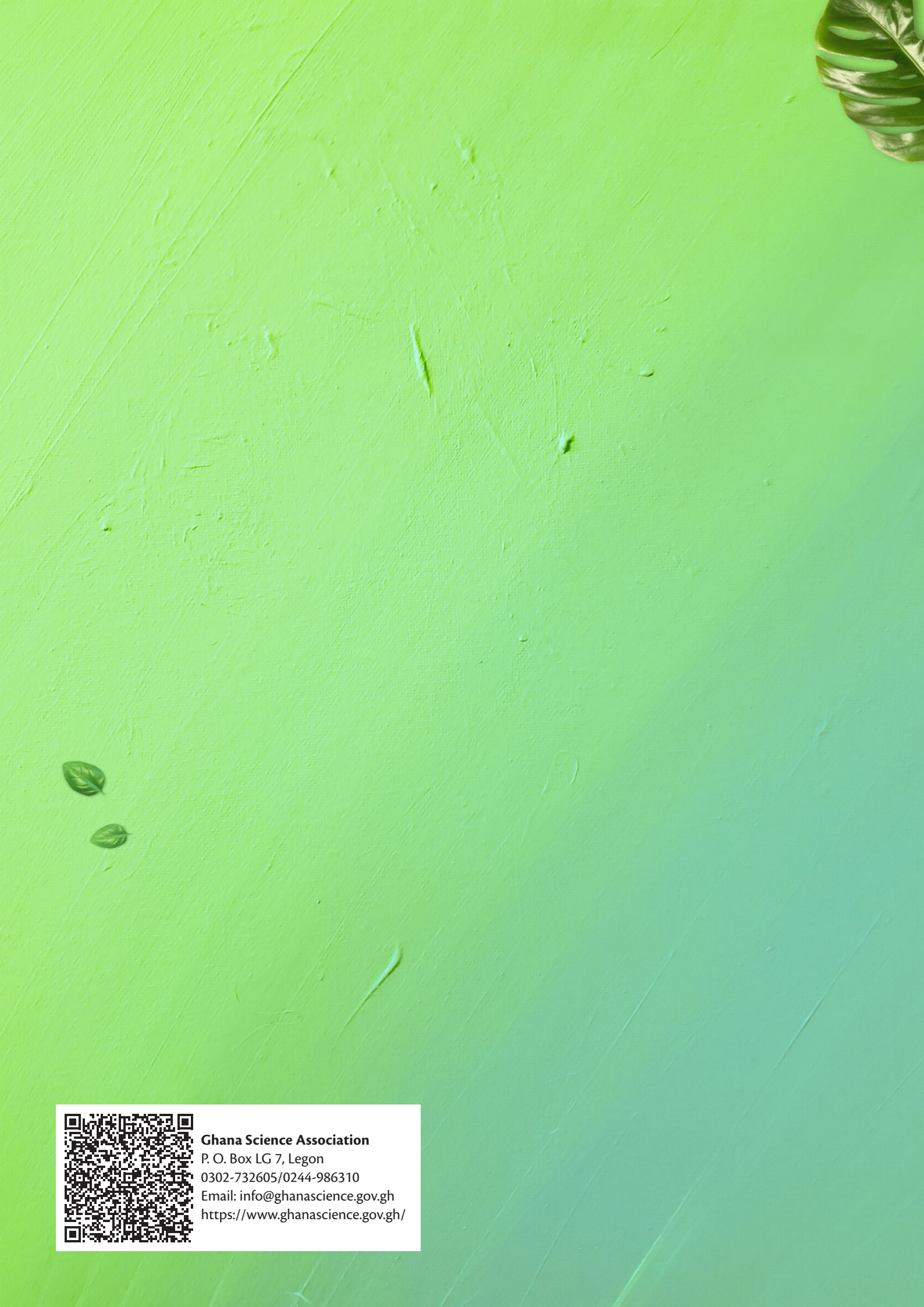
www.owlcation.com/social-sciences/Psychology-and-its-Importance

www.quora.com/What-is-the-role-of-psychology-in-education

www.ungcmyb.org/post/sustainable-development-goal-3-good-health-and-well-being

www.educerecentre.com/challenges-of-inclusive-education

www.edumilestones.com/blog/details/The-role-of-career-counselling-in-economic-development



Ghana Science Association
P. O. Box LG 7, Legon
0302-732605/0244-986310
Email: info@ghanascience.gov.gh
https://www.ghanascience.gov.gh/