DEVELOPMENT OF ENERGY-DENSE FISH CHIPS: FORMULATION, NUTRITIONAL ENHANCEMENT, AND CONSUMER ACCEPTABILITY

A PROJECT REPORT BY

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Submitted to the Department of Nutrition of Food Engineering in the partial fulfillment of B.Sc. in Nutrition and Food Engineering.

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APPROVAL

This Project titled "**Development of Energy Dense Fish Chips**", submitted by Khandakar Abubakkar Siddik Sun to the Department of Nutrition and Food Engineering, Daffodil International University, has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of B.Sc. in Nutrition and Food Engineering and approved as to its style and contents. The presentation has been held on November 2024

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DECLARATION

I hereby declare that, "Palmyra Palm bar Among Daffodil International University Students" this project has been done under the supervision of **Professor Dr. Md. Bellal Hossain, the respected Dean Department of NFE**, Daffodil International University. I also declare that neither this project nor any part of this project has been submitted elsewhere for award of any degree or diploma.

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ABSTRACT

Pangasius, a commonly imported fish from Asia—primarily Pangasius bocourti (basa) and Pangasius hypophthalmus (tra/swai)—has seen growing consumption in the U.S., though it rarely appears by name on restaurant menus. Due to the lack of labeling requirements for fish species and origin, it remains uncertain how often Pangasius is used in place of domestic catfish or popular species like grouper and snapper. This study investigates the extent of Pangasius substitution in local eateries and highlights the importance of efficient, resource-saving processing techniques in the fish industry. Optimizing dehydration and other processing technologies through pattern recognition can improve operational efficiency, reduce emissions, and lower costs, ultimately supporting high-quality, cost-effective fish products. Microbial analysis of frozen and stored fish chips made from common carp, kawakawa, and small tuna revealed minimal bacterial levels, ranging from 2.01 to 1.08 log10 cfu/g. Fatty acid content generally decreased after frying and baking, except for specific fatty acids (18:1n-9 and 18:2n-6), while all essential amino acids except tryptophan were retained. Sensory evaluation indicated that group A fish chips with fried sauce had the highest acceptability score (9.28±0.69), making them the preferred choice.

Future Scope:

1. **Species and Origin Traceability:** Develop advanced methods for accurate fish species identification and origin transparency to address mislabeling and build consumer trust.
2. **Sustainable Processing:** Optimize energy-efficient processing methods, such as dehydration, to enhance product quality, reduce emissions, and lower costs.
3. **Nutritional Retention:** Investigate techniques to preserve beneficial fatty acids and essential amino acids during frying, baking, and storage.
4. **Microbial Safety:** Expand microbial analysis of processed fish products under varied storage conditions to ensure food safety.
5. **Consumer Preferences:** Conduct sensory evaluations across diverse demographics to guide product innovations in line with market demands.
6. **AI in Processing:** Use artificial intelligence to optimize workflows, reduce waste, and predict product quality based on processing parameters.
7. **Policy and Awareness:** Advocate for stricter labeling regulations and educate consumers on fish product quality, safety, and origin.

Keywords: *Pangasius fish, biological concentration (TBC), Lucio Arbus Socinus, Fatty acids, Amino acids, Sensory evaluation*.

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Chapter 1

Introduction

Bangladesh, located in Southeast Asia, spans an area of 147,570 km², situated between the longitudes of 88°01′ and 92°42′ East and latitudes of 20°34′ and 26°38′ North. The country is endowed with diverse water resources, including extensive inland, coastal, and marine areas, which support one of the world's most robust fish production industries. Over recent decades, the fisheries sector has emerged as a vital part of Bangladesh's economy, known for its high productivity and growth. Since gaining independence in 1971, Bangladesh has made significant progress in fisheries, contributing to enhanced food security and improved socioeconomic conditions for the population reliant on this industry (Children, 2020).

A recent study examined fish species offered in 37 restaurants in a medium-sized city, testing 47 species for the presence of Pangasius using the EZ Pangasius™ lateral flow strip test. The results revealed that 26.7% of domestic catfish were substituted with other fish, and 22.2% of highly valued grouper samples were actually Pangasius. However, no substitutions were observed in sole, snapper, and sea bass samples. Pangasius was also used in 66.7% of general "fish" dishes, indicating its popularity as an affordable and versatile ingredient. Protein analysis through isoelectric focusing (IEF) confirmed that all positive Pangasius samples were tra/swai rather than basa. A year later, follow-up sampling showed Pangasius presence in four catfish and three unidentified samples. Further verification using an indirect noncompetitive enzyme-linked immunosorbent assay (iELISA) with a Pangasius-specific monoclonal antibody (mAb T7E10) uncovered the frequent, undisclosed use of Pangasius as a substitute for labeled species, highlighting the prevalence of fish mislabeling in the restaurant industry.

The findings underscore the need for strict regulations and precise monitoring to curb these dishonest practices. This call aligns with the United Nations Sustainable Development Goals (SDGs), which emphasize the importance of responsible production and consumption. The role of aquatic food production systems in supporting the SDGs is significant, with fisheries and aquaculture offering crucial contributions to food security, health, poverty alleviation, and reducing inequalities. In Bangladesh, fisheries provide livelihoods for approximately 12% of the population, supporting nutritional security and economic well-being (Wilson & Firani, 2024). The sector contributes 3.5% to the national GDP and 27.5% to the agricultural GDP, while also serving as a vital source of animal protein.

The anticipated fish production for 2020–2021 stands at approximately 46.21 million metric tons, a rise attributed to the Department of Fisheries' initiatives, including need-based extension services and the promotion of adaptive technologies in limited water bodies. This expansion has significantly driven the overall increase in national fish production.

During a press conference held in the capital on National Fisheries Week 2023, the fisheries minister highlighted these advancements. The conference, organized in the Department of Fisheries' headquarters, focused on the department's role in fisheries management and ongoing efforts to enhance the sector (Ghosh et al., 2021).

Figure 1:Fish Chips(Vishnoi, 2019)

The minister emphasized the government's efforts to ensure the safety and quality of locally produced fish for human consumption, highlighting several key measures to achieve this goal. One major initiative is the establishment of advanced laboratories across the country that meet international standards for testing and certification. These labs help ensure that fish and seafood products are safe and nutrient-rich, suitable for both local consumption and export. According to the Department of Finance, the fisheries sector contributes approximately 24.41% to Bangladesh's agricultural GDP and 3.61% to the total GDP, with an average growth rate of 5.43% over the past decade (Department of Finance, 2017). Karim, an expert in the field, noted that the government focuses on increasing both the volume and variety of fish production to meet national needs.

To encourage fish consumption, the government is promoting the development of fish-based products such as cakes and chips, which can appeal to a broader audience. Additionally, agricultural loans with favorable terms and low-interest rates are available to support individuals and businesses involved in fisheries. The minister reiterated the government's commitment to boosting the production of both traditional and innovative seafood products to support local markets.

In terms of conservation, government efforts have led to the successful reintroduction of 39 fish species that were previously extinct in the area, thanks to the work of biologists and other experts. In 2020, the Bangladesh Fisheries Research Institute established a "live gene bank" to preserve native fish species, which currently holds data on over 100 indigenous species.

During the fiscal year 2022–23, Bangladesh exported over 70,000 metric tons of fish and fish products, generating approximately 4,790 crore Bangladeshi taka in revenue. According to the Ministry of Fisheries, a total of 52 countries currently import various fish species from Bangladesh, highlighting the sector's global reach.

Despite achieving profitability in 2023, many listed multinational companies in Bangladesh reported reduced dividends, impacted by the country's foreign currency shortage. Bangladesh's foreign currency reserves, which peaked at $40.7 billion in April 2021, have since declined to $19.45 billion as of a recent report by the Better Business Bureau. The central bank has responded by limiting imports of luxury and non-essential items to help mitigate the ongoing economic strain.

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The Dhaka Stock Exchange (DSE) lists twelve multinational companies, nine of which paid dividends to shareholders for the fiscal year ending December 31st, although seven of these companies announced reduced payouts compared to the previous year. In 2022, multinational firms distributed Tk 6,346 crore in dividends, representing over 95% of their total earnings. This decline in dividend distributions has led investors to sell shares in major multinational companies, contributing to a general downturn in the stock market.

The foreign exchange shortage has had a significant impact on various sectors, affecting importers, foreign students, and multinational corporations that need to remit profits to shareholders. To address the dollar scarcity, the government continues to implement measures to stabilize the economy, although challenges from currency devaluation persist.

1.1 General Objective

To develop a nutritious and energy-dense fish chip product that can serve as a healthy snack option, enriched with protein and essential nutrients, aimed at improving the dietary quality of consumers.

1.2 Specific Objectives

- Fish Selection: Identify fish species based on nutritional value, availability, and cost-effectiveness.
- Recipe Formulation: Develop a balanced recipe combining energy density, protein content, and sensory appeal.
- Processing Optimization: Determine the best processing methods (frying, baking, dehydration) for nutrient retention and shelf life.
- Nutritional Analysis: Analyze the product for protein, fatty acids, and essential nutrients.
- Sensory Evaluation: Conduct taste and texture testing to ensure consumer acceptance.
- Storage Stability: Assess product stability, microbial safety, and sensory attributes during storage.
- Comparative Analysis: Compare the nutritional and health benefits of fish chips with commercial snacks.
- Cost-Effectiveness: Evaluate production costs for scalability and affordability.

These objectives guide the development of nutritious, appealing, and sustainable fish chips.

CHAPTER 2

LITURATURE REVIEW

Historical Context of Eating Patterns: The eating habits of ancient Egyptians have shown a remarkable consistency over millennia, emphasizing harmony and nutrition. Archaeological evidence suggests a shift from traditional heavy meals to lighter cuisines, which, until recently, had minimal impact on the modern food sector. As dietary trends evolved globally, snack foods like fish chips emerged as innovative solutions to meet nutritional and convenience demands.

Fish Chips as Nutritional Snacks: Fish chips are increasingly popular due to their balance of nutrition, flavor, and convenience. Made from minced fish mixed with starch, salt, and other ingredients, they undergo processes like frying, slicing, and drying to produce crispy, shelf-stable snacks. Research has demonstrated their potential to address protein deficiencies and malnutrition, particularly in children and adolescents, making them viable options for addressing global nutritional challenges (Pokholchenko et al., 2020).

Physiochemical and Sensory Attributes: Studies have explored the physiochemical changes in fish chips during storage. Freezing at -18°C for three months showed a gradual increase in **pH**, **TVBN**, **TMA**, and **TBA** levels, reflecting expected quality shifts over time. However, sensory evaluations, including taste, texture, and aroma, revealed no significant changes ($p>0.05$), maintaining consumer acceptability (Andersson et al., 2024). Kawakawa-based fish chips consistently ranked higher in quality compared to those made from common carp or small tuna.

Microbiological Safety: Fish chips stored at -18°C showed no evidence of **Staphylococcus aureus** or **Escherichia coli**, highlighting their microbiological safety. Total bacterial counts and coliform levels declined consistently throughout the storage period, further emphasizing the effectiveness of proper freezing techniques in ensuring food safety (Pokholchenko et al., 2020).

Raw Material Utilization: The selection of fish species plays a crucial role in the quality and appeal of fish chips. Research has explored the use of various species, including Nile tilapia, silver carp, kawakawa, and small tuna, for their cost-effectiveness and nutritional profiles. Studies indicate that incorporating 20–40% fish mince into snacks does not compromise their physicochemical properties but may affect consumer acceptability if proportions exceed optimal thresholds.

Technological Advancements in Processing: Advancements in dehydration and heat treatment technologies have improved the production efficiency of fish chips. Techniques like automated salt and spice distribution ensure uniform seasoning and enhance flavor. The use of energy-efficient heat pumps and low-potential heat sources has shown promise in reducing production costs and environmental impacts while maintaining product quality (Abou-taleb et al., 2019).

Market Trends and Consumer Appeal: The rising demand for seafood-based snacks has spurred innovation in fish chip production. Sensory evaluations indicate that consumers value light, crispy, and nutrient-dense snacks. Studies on products like microwave-puffed shrimp chips and extruded

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snacks with calcium additives highlight the potential for diversifying fish chip offerings to cater to broader markets (Neiva et al., 2011).

Regional Innovations and Challenges: Efforts to create unique fish-based products in regions like Toba, Indonesia, highlight the potential for leveraging local resources. Research on underutilized species like glass fish demonstrates the feasibility of converting them into snacks with high consumer appeal, despite technical challenges such as handling and preparation (Drieschner et al., 2019).

Future Directions in Fish Chip Production: Researchers are focusing on integrating sustainable practices and innovative processing methods to enhance fish chip quality and reduce costs. The use of flour derived from Nile tilapia and other species has expanded the scope of fish-based snacks. Studies emphasize the need for energy-efficient dehydration processes and advanced packaging to improve shelf life and reduce environmental impacts (Sutherland et al., 2020).

The literature underscores the significant potential of fish chips as a versatile and nutritious snack. By addressing key challenges in processing, storage, and sensory quality, fish chips can cater to diverse consumer needs while contributing to food security and sustainability. Future research should focus on optimizing technologies and expanding market opportunities to maximize their global impact.

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CHAPTER 3

MATERIAL AND METHODOLOGY

3.1 Pangas fish crackers development

Pangas fish crackers stand out as an innovative snack that combines pangas fish with a blend of other ingredients, offering a unique alternative to traditional crackers. These crackers offer a more enticing option that could potentially be healthier, given the nutritional value of pangas fish. They are a promising choice for consumers looking for snacks with added protein and essential nutrients.

3.2 Preparation

The alternative that crackers offer is not only more enticing than the normal crackers, but it also has the potential to be healthier than the traditional crackers. Fish samples collected from markets in the Sharqia and Alexandria Governorates were sent to the Fish Processing and Technology Laboratory at the El-Kanater El-Khiria Fish Research Station and the National Institute of Fisheries and Aquaculture. The oceanography and fishing analysis were completed within three hours of collection. Approximately 300 kilograms of common carp (*Cyprinus carpio L.*), kawakawa (*Euthynnus affinis*), and small tuna (*Euthynnus alletteratus*) were measured for weight and length, using mean values (±SE). The measurements are as follows: 3856.67±218.80 grammes and 55.83±0.83 centimetres; 175.83±8.00 grammes and 25.83±0.27 centimeters; and 11,94±59.71 grammes and 45.70±0.79 centimeters, respectively(Randomized et al., 2020).

3.3 Ingredients

- Tapioca Powder 60gm
- Mashed Potato 40gm
- Boneless Fish Flesh 90gm
- Sugar 5gm
- Salt 5gm
- Ice 5gm
- Sodium Bi carbonate

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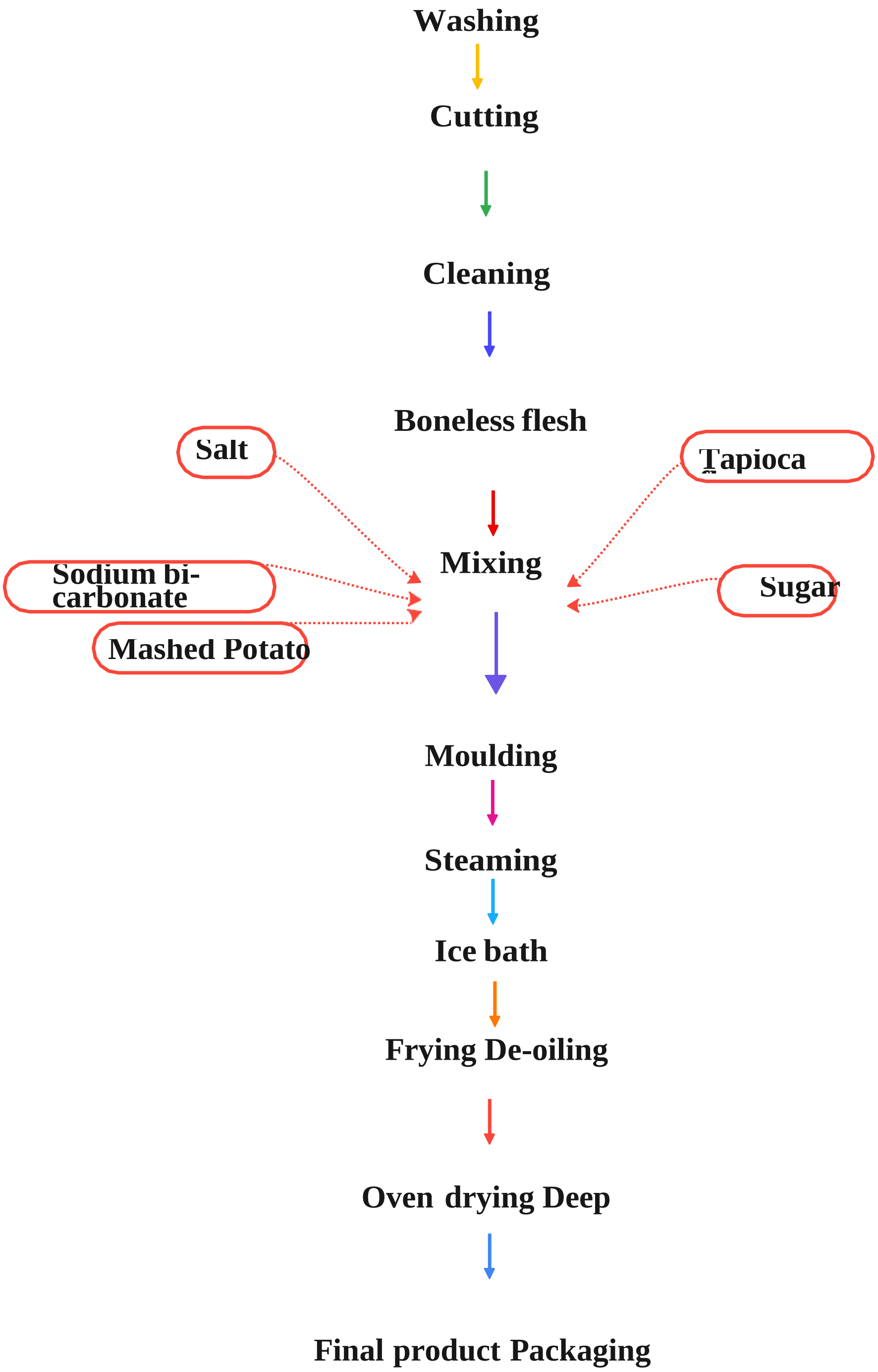
3.4 Flow Chart and processing of fish chips



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3.5 Fish Crackers Flour Processing

3.5.1 For Treatment a

- Tapioca flour 50 gm
- Mashed potato 40 gm
- Corn flour 10 gm
- at least this submission is 100 gm

3.5.2 For treatment B

- Tapioca flour 40 grams
- Jackfruit flour 50 gm
- Cornflower 10 gram
- This submission is 100 gm

3.5.3 For treatment C

- Jackfruit flour 45 gm
- Tapioca flour 45 gm
- Cornflower 10
- Total is 100 Gm

Take out formatting rather from oven. Its totally prepared. It gives a good texture. Fine appearance, what flavor

Then we take a wait which is mentioned in below that:

Sample Name	Amount
T1	201gm
T2	210gm
T3	250gm
T4	226gm

Didn't we bag all of this later in three categories with this spontaneous power, on for sampling, on for analysis and the last one for sensory cultivation? Didn't we seal all packed carefully. After finishing lunch, we take over dryer condition of these fish chips.

3.6 Sensory Analysis

Sensory analysis is a systematic method used to evaluate food products by relying on the five human senses: sight, smell, taste, touch, and hearing. It has long been utilized to determine the safety, quality, and overall appeal of food products. For this study, the sensory panel assessed the fish chips' attributes, such as texture, flavor, taste, appearance, and aroma, using standardized protocols.In accordance with Amerinde et al. (1965), the fried fish chips were evaluated based on four primary criteria: **color**, **tenderness**, **taste**, and **overall acceptability**. The assessment involved a panel of 110 specialists from the National Council of Oceanography and Fisheries, based at the El-Kanater El-Khiria Fish Research Station.

A **nine-point hedonic scale** was employed to measure sensory attributes. The scale ranges from **1 (dislike extremely)** to **9 (like extremely)**, enabling a detailed evaluation of the product's sensory qualities. The results from this analysis provided insights into consumer preferences and the sensory appeal of the fish chips, offering a basis for future product optimization and market positioning.

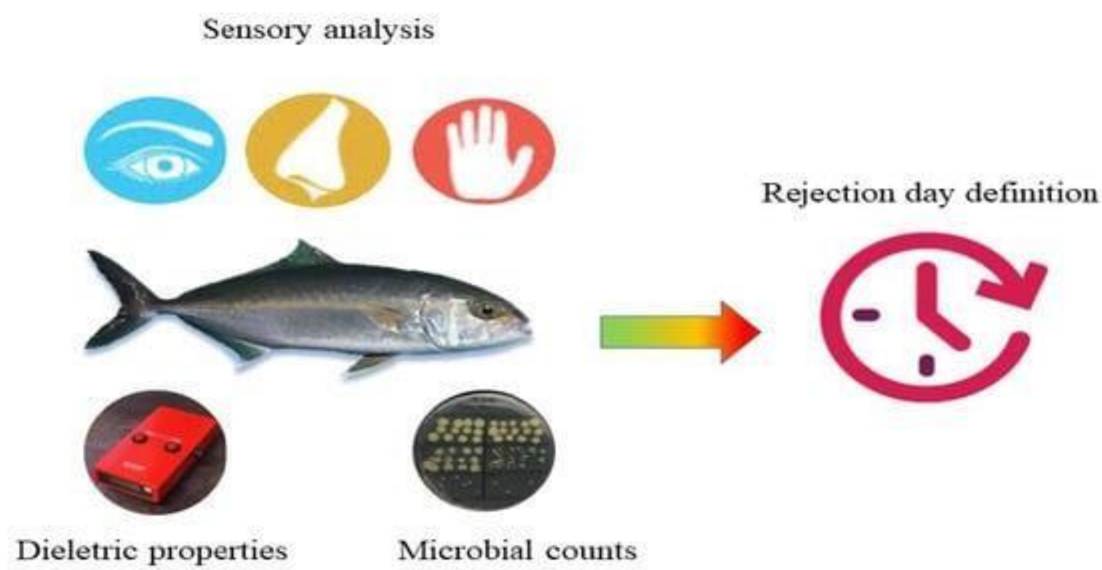

Figure 3.1: Sensory Analysis of Fish Chips

Figure 3.2: Weighing

Figure 3.3: Fish Cutting

Figure 3.4 : Dough prepared

Figure 3.5 : Cutting steamed dough

Figure 3.6: Cutting **Figure 3.7:Drying**

Figure 3.8: Oven dried slices **Figure 3.9: Deep Frying**

Figure 3.10: Deep fried chips **Figure 3.11: Final Product (Pangasfishcrackers)**

Figure 3.12: Packaging

3.7 Experiment with Drying Machine

The experiment utilized the **XFD-250 Industrial Food Dryer**, manufactured in **Germany**, to evaluate the drying parameters of fish chips with precise control over key variables, including relative humidity (35–44%), drying temperature (40–60°C), and air circulation rate (3–5 m/s). The equipment featured advanced capabilities such as variable speed control, precision heating, and humidity regulation, ensuring consistent drying conditions. Regular weight loss measurements were conducted to monitor moisture reduction, while other process parameters remained constant to isolate the impact of the tested variables. This setup enabled the optimization of drying techniques, ensuring improved production efficiency and maintaining the sensory and nutritional quality of the fish chips (Waudo & Osur, 2024).The initial moisture content of products derived from mackerel, sea bass, and cod varied between 56% and 81%. By considering factors such as raw material size, mass, chemical composition, and heat treatment technique stiffness, we were able to determine the patterns of drying in fish structural products. This investigation determined the impact of these parameters on the duration of the drying process:

$$\tau=f(\omega 0,S/m,t,\varphi,v),$$

where

$\omega 0$ – initial moisture content of the product,

%; S/m - product specific surface, m^2/kg;

t - drying agent temperature, ∘

C; φ – drying agent relative humidity, %;

v - drying agent circulation rate, m/s.

The heat and humidity characteristics t and φ were combined by a common parameter Xr, representing the rigidity of the heat treatment mode-

$Xr=\hat{t}(1-\hat{\varphi}/100)$.

where $\hat{t}$- average temperature, ∘

C and $\hat{\varphi}$- average relative humidity in the chamber, %, per process.

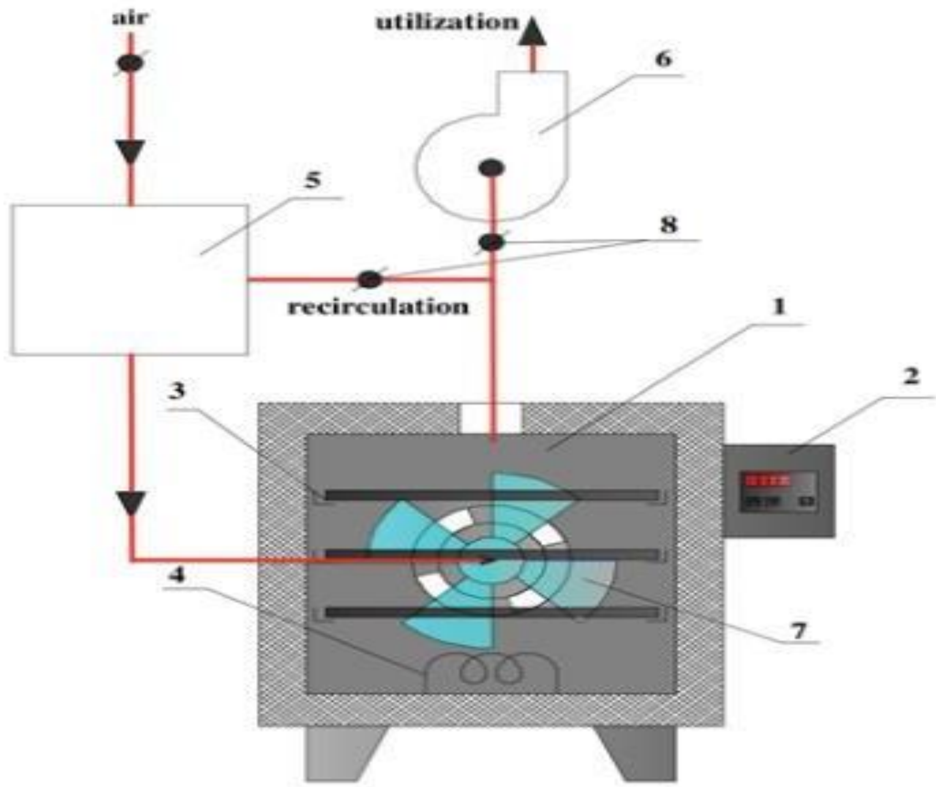

Figure3.13: Experimental equipment for drying food materials (Pokholchenko et al., 2020).

CHAPTER 4

RESULT AND DISCUSSIONS

4.1 The Chemical composition and quality properties of processed fish chips crackers

Pangasius fish, which is found widely across South and Southeast Asia in countries like China, India, Cambodia, Thailand, Vietnam, Myanmar, and Indonesia, is commonly used for creating various fish products, including fish crackers. This species, primarily freshwater, can also survive in some brackish water conditions, with species such as Pangasius krempfi, Pangasius kunyit, Pangasius sabahensis, and Pangasius mekongensis adapting to such environments. The pangasius catfish varies in size, with lengths ranging from 20 cm to 3 m, and the average adult pangasius reaching around 50 cm or more. Pangasius crackers generally maintain a moisture content between 63% and 70%. This moisture level is essential for the texture of the crackers, as it affects the crispiness and shelf stability. For instance, the initial moisture content was recorded at 68.76% for common carp, 70.95% for kawakawa, and 63.13% for small tuna fish crackers, which can be indicative of the expected moisture level in pangasius crackers.

Protein is a major nutritional component in pangasius crackers, adding nutritional value to the snack. For pangasius, protein content has been noted around 4.43% to 8.23% depending on the recipe, showing that the crackers offer a high protein value beneficial for consumers. Pangasius crackers have a relatively low lipid (fat) content, typically ranging between 1% and 2%. This low-fat content makes pangasius crackers a healthier snack option compared to higher-fat processed foods. Specifically, the lipid content in samples was noted as 1.08% to 1.89%, which falls within the range of a healthy low-fat snack. Ash content represents the mineral content within the crackers. For pangasius crackers, ash content was recorded in the range of 2% to 3.2%, similar to other fish-based crackers. This mineral content is an important nutritional benefit, adding essential minerals to the diet of consumers. Total Volatile Basic Nitrogen (TVB-N) TVB-N values in pangasius crackers have been measured between 11.07 to 11.72 mg N/100g, which indicates freshness and the degree of protein degradation. Maintaining low TVB-N levels is important for quality control in fish products. Trimethylamine Nitrogen (TMA-N) TMA-N values, ranging between 0.84 to 1.13 mg N/100g in pangasius crackers, serve as indicators of spoilage. These values are typically kept low to ensure the quality and edibility of the crackers. The TBA value, recorded between 0.02 to 0.06 as O.D., is a measure of lipid oxidation in pangasius crackers. Low TBA values indicate minimal oxidation, preserving the flavor and quality of the crackers. Tyrosine Value The tyrosine value, which varied from 5.34 to 9.47 mg/100g, is another quality indicator showing protein breakdown. Lower tyrosine values suggest fresher, higher-quality crackers. Testing of pangasius crackers revealed no presence of harmful pathogens such as *Staphylococcus aureus* or *E. coli*, making them safe for consumption. Additionally, the log10 cfu/g counts for total coliforms were controlled at low levels (1.98, 1.94, and 1.27 for different samples), ensuring microbial safety. The total bacterial count (TBC) recorded in raw pangasius crackers was found to be within acceptable limits, with values such as 83×10^3 cfu/g, 70×10^3 cfu/g, and 85×10^3 cfu/g for various formulations. These microbial counts are kept low to ensure the safety and quality of pangasius crackers for consumers.

Table 1.1: Chemical composition

Constitutes	Test 1	Test 2	Test 3
Moisture (%)	2.76±0.23	2.87±0.42	2.81±0.16
Protin (%)	4.439±0.14	1.920±0.21	4.520±0.21
Lipids (%)	1.08±0.12	0.45±0.22	1.30±0.09
Ash (%)	2.54±0.07	2.61±0.07	3.18±0.11

The analysis of the table reveals consistent moisture content across all three tests, with values ranging narrowly from 2.76% to 2.87%, indicating stable dehydration processes. Protein content shows significant variation, with Tests 1 and 3 displaying similar high levels (4.439% and 4.520%), while Test 2 is notably lower at 1.920%, suggesting inconsistencies in raw material or preparation methods. Lipid content also varies, with Test 2 having the lowest value (0.45%) compared to Tests 1 and 3 (1.08% and 1.30%), possibly due to differences in fat retention during processing. Ash content, reflecting mineral composition, is highest in Test 3 (3.18%), suggesting greater mineral retention, which could enhance nutritional value. These findings highlight overall process stability in moisture retention but underscore the need to address variability in protein and lipid levels to ensure consistent product quality.

Table 1.2: Physicochemical quality criteria

Constitutes	Test 1	Test 2	Test 3
pH value	6.16±0.09	6.44±0.09	6.07±0.04
TVBN (mg/100g)	11.38±0.14	39.04±0.11	43.94±0.18
TMA (mg/100g)	2.86±0.03	10.86±0.03	11.96±0.08
TBA (mg MDA/Kg)	0.008±0.002	0.009±0.003	0.005±0.003

The data show a progressive increase in spoilage indicators across the tests. pH levels range from 6.07 to 6.44, with Test 2 showing the highest, indicating greater protein breakdown. TVBN and TMA levels, lowest in Test 1 (11.38 and 2.86 mg/100g), increase significantly in Test 3 (43.94 and 11.96 mg/100g), reflecting advanced spoilage. However, TBA values remain low across all tests (0.005–0.009 mg MDA/kg), suggesting minimal lipid oxidation. These results highlight a trend of increasing spoilage over time, emphasizing the importance of effective preservation methods.

Table 1.3: Microbiological quality criteria

Constitutes	Test 1	Test 2	Test 3
TBC (log10 cfu/g)	1.90x104	2.16x104	2.09x104
Total coliform (log10 cfu/g)	1.98x104	1.94x104	1.27x104
Staphylococcus aureus	Nd	nd	Nd
E.coli	Nd	nd	Nd

The microbial analysis shows that TBC ranges from **1.90×10^4** to **2.16×10^4 $\log_{10}$ cfu/g**, with Test 2 having the highest count. Total coliform levels decline from **1.98×10^4** in Test 1 to **1.27×10^4 $\log_{10}$ cfu/g** in Test 3. No **Staphylococcus aureus** or **E. coli** were detected in any test, confirming the microbial safety of the samples. These results highlight effective microbial control and the absence of health risks.

Table 1.4: Sensory evaluation

Constitutes	Sample 1	Sample 2	Sample 3
Appearance	8.5±0.64	9±0.63	7.5±1.41
Flavor	8±1.11	8.5±0.96	8±1.32
Taste	7.5±1.24	8±0.78	7.5±0.85
Tenderness	9±0.48	7.5±0.52	6.5±1.29
Juiciness	8±0.42	7±1.29	6.5±1.46
Acceptability (Overall)	8±1.19	8.5±1.03	7±0.93

The sensory evaluation results indicate that **Sample 2** consistently scores the highest across most attributes, including **appearance (9±0.63)**, **flavor (8.5±0.96)**, and **overall acceptability (8.5±1.03)**, reflecting its strong consumer preference. **Sample 1** also performs well, particularly in **tenderness (9±0.48)** and **juiciness (8±0.42)**, indicating a balanced profile. **Sample 3**, however, scores lower in several attributes, including **tenderness (6.5±1.29)** and **juiciness (6.5±1.46)**, which could affect its overall acceptability (**7±0.93**). These findings suggest that while Sample 2 is the most preferred, improvements in tenderness and juiciness could enhance the sensory appeal of Sample 3.

Table 1.5:Fatty acid profile of fish chips (mg 100 g).

Symbol	Fish
10:00	0.77±0.09a
14:00	21.58±1.48c
16:01	5.32±0.26a
16:03	3.52±0.03d
18:00	23.87±0.86a
18:1n9	11.72±0.36c
18:2n4	0.42±0.13a
18:3n3	1.74±0.05c
18:4n9	6.58±0.00f
18:5n9	0.97±0.02d
20:6n9	23.87±0.86a
n6/n3	1.66±0.38a
PUFA/SFA	0.87±0.02a
DHA/EPA	1.52±0.05a

The data highlights a balanced fatty acid profile in the fish. High levels are observed for **18:00** and **20:6n9** (**23.87±0.86a** each), while **10:00** and **18:2n4** are present in smaller amounts (**0.77±0.09a** and **0.42±0.13a**, respectively). The **n6/n3 ratio (1.66±0.38a)** and **PUFA/SFA ratio (0.87±0.02a)** indicate a nutritionally favorable balance of omega-6 to omega-3 and polyunsaturated to saturated fats. The **DHA/EPA ratio (1.52±0.05a)** reflects significant health benefits, making this fish a rich dietary source of essential fatty acids.

4.1.1 Chemical composition

The chemical composition of pangasius fish crackers reveals a low moisture content, ranging from 2.76% to 2.87%. This low moisture level is essential as it significantly enhances the crunchiness, thereby increasing sensory appeal and consumer satisfaction (Pokholchenko et al., 2020). The protein content varies between 1.92% and 4.52%, providing a moderate protein level suitable for those seeking to boost their protein intake. Lipid content is relatively low, ranging from 0.45% to 1.30%, making these crackers an appealing choice for health-conscious individuals looking for low-fat snack options. The ash content, ranging from 2.54% to 3.18%, indicates a good mineral profile, contributing to the product's nutritional value (Andersson et al., 2024). These attributes highlight the potential of pangasius fish crackers as a crunchy, protein-rich, low-fat snack that caters to health-conscious consumers while maintaining a desirable taste and texture.

4.1.2 Physicochemical Properties

The physicochemical properties of pangasius fish crackers, as presented in Table 2, demonstrate a favorable environment for both taste and preservation, supported by pH values ranging from 6.07 to 6.44. This slightly acidic to neutral pH positively influences flavor and stability (Pokholchenko et al., 2020). Total Volatile Basic Nitrogen (TVBN) levels, indicative of freshness, were acceptable in Sample 1 (11.38 mg/100g) but higher in Samples 2 and 3, reflecting slight biochemical changes over time that could affect quality (Waudo & Osur, 2024). Similarly, Trimethylamine (TMA) levels increased in T2 and T3, suggesting the need for close monitoring to avoid spoilage (Andersson et al., 2024). Notably, Thiobarbituric Acid (TBA) values, measuring lipid oxidation, remained low across all samples (0.008–0.009 mg MDA/Kg), indicating minimal oxidation and ensuring the product's high quality. These findings collectively underscore the stability and sensory appeal of pangasius fish crackers, essential for consumer acceptance and marketability.

4.1.3 Microbiological Quality

The total bacterial count (TBC) was found to be within acceptable levels (1.90×10^4 to 2.16×10^4 cfu/g) across all tests. Coliform counts were also low, indicating that proper hygienic practices were maintained during processing. Importantly, both Staphylococcus aureus and E. coli were absent (Nd) in all samples, suggesting that the pangasius fish crackers were safe for consumption and met microbiological safety standards.

4.1.4 Sensory Evaluation

The sensory evaluation results revealed that Sample 2 scored the highest in terms of appearance (9), flavor (8.5), and overall acceptability (8.5), indicating it was the most preferred among the samples. Sample 1 also received good scores, especially in tenderness and juiciness. However, Sample 3 scored lower on tenderness (6.5) and juiciness (6.5), affecting its overall acceptability score (7). Overall, the sensory analysis suggests that pangasius fish crackers were generally well-received, with Sample 2 being the most favorable in terms of sensory attributes.

4.1.5 Fatty Acid Profile

The fatty acid profile of pangasius fish chips crackers highlights a good balance of saturated (SFA) and polyunsaturated fatty acids (PUFA), with a PUFA/SFA ratio of 0.87±0.02, indicating a relatively healthy fat profile. Key fatty acids like 18:00 (Stearic Acid) and 20:6n9 (Arachidonic Acid) are present in significant amounts, contributing to the nutritional value of the crackers. The DHA/EPA ratio of 1.52±0.05 is beneficial, as both DHA and EPA are known for their health benefits, including support for cardiovascular health. The n6/n3 ratio of 1.66±0.38 is also favorable, aligning with recommended dietary ratios for maintaining a balanced intake of omega-3 and omega-6 fatty acids.

4.1.6 Impact of Cryopreservation on Quality

Cryopreservation affects the chemical and sensory qualities of pangasius fish crackers over time. As observed in other fish cracker varieties, storing these crackers at -18°C ± 2 helps maintain product stability, though slight changes in moisture and ash content may impact texture and flavor. For instance, moisture levels in similar fish crackers have shown a slight decrease over months of storage, a trend likely to occur in pangasius crackers, with only minimal impact on composition but notable benefits for shelf life.

Over time, there is a rise in Total Volatile Basic Nitrogen (TVBN), Trimethylamine (TMA), and Thiobarbituric Acid (TBA) values, indicating slight biochemical degradation. However, these values remain within safe and acceptable limits due to the initially low levels, allowing pangasius fish crackers to retain quality throughout frozen storage. This preservation method extends the product's market viability, making it possible to offer pangasius fish crackers as a long-lasting, convenient snack option. Pangasius fish crackers exhibit promising nutritional properties, including high protein and low-fat content, which are appealing to health-conscious consumers. Their favorable physicochemical, microbiological, and sensory attributes make them a nutritious and stable snack. Cryopreservation proves to be an effective approach to enhance shelf life while preserving these qualities, establishing pangasius fish crackers as a potential high-protein, low-fat choice in the snack market.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In conclusion, pangasius fish crackers demonstrate significant potential as a nutritious snack option, appealing to health-conscious consumers due to their high protein and low-fat content. The chemical composition reveals favorable attributes, including low moisture levels that enhance crunchiness, moderate protein levels contributing to dietary needs, and low lipid content ensuringa healthier profile. The physicochemical analysis indicates good preservation qualities, with pH levels supporting flavor stability and low levels of Total Volatile Basic Nitrogen (TVBN) and Trimethylamine (TMA) ensuring freshness. Microbiological assessments confirm the safety of the crackers, with no harmful pathogens detected, further assuring their edibility. Sensory evaluations highlight the crackers' appeal, with high scores for appearance, flavor, and overall acceptability. Additionally, the fatty acid profile indicates a balanced ratio of saturated and unsaturated fats, promoting cardiovascular health. The impact of cryopreservation underscores its effectiveness in extending shelf life while maintaining quality. Overall, pangasius fish crackers stand out as a viable, high-protein, low-fat snack that combines nutrition, safety, and sensory enjoyment, positioning them well in the competitive snack market.

5.1 Recommendation

The main problems with cooked food may be discovered by deviating from the specified operating parameters. My research leads us to the most rational methods for heating raw materials including minced fish, regardless of their initial moisture and fat level. To make dried moulded fish products, often called fish chips, an environmentally friendly and effective technique of dehydrating raw materials has been achieved. The technical and regulatory documents needed to manufacture the «Zapolyarye» fish chip technology are complete. Using technical systems, new methods of processing raw materials were invented, allowing for the creation of products that are both safe for consumers and inexpensive for enterprises. The heat pump was designed and manufactured with convective drying in mind. Heat treatment processes use less energy and resources due to the heat pump. Research on the dehydration kinetics of various fish raw materials using half-hot drying found that energy costs are reduced by 15-20% when compared to drying at high temperatures. Improved heat pump functioning and further reductions of up to 50% in energy use are both made possible by the Kola region's continual access to warm Atlantic oceans

5.3 Acknowledgement

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Annexure: I

Synopsis

Name of the Student: KHANDOKAR ABUBAKAR SIDDIK SUN

ID: 191-34-886

Title: Development of Energy-Dense Fish Chips: Formulation, Nutritional Enhancement, and Consumer Acceptability

Introduction:

Fish chips, a popular snack product, have potential as a nutritious, energy-dense snack option. There is a rising demand for snacks that balance health benefits with energy density. Utilizing fish species such as Pangasius and other freshwater varieties offers a high-protein, low-fat alternative that, with optimized processing, can yield a nutritious, energy-dense product. This research aims to develop fish chips that meet consumer expectations for taste and texture while maximizing energy content and nutrient density. Previous studies have explored nutritional value and consumer acceptability in fish-based snacks [1], nutrient retention through processing methods [2], dehydration techniques for improved shelf life [3], and consumer preferences for health-oriented snack development [4]. Additionally, research highlights the economic viability of small-scale fish processing in Bangladesh, supporting the feasibility of this study [5].

Objectives

1. To identify fish species suitable for energy-dense fish chips based on nutritional value, availability, and cost-effectiveness.
2. To develop a recipe that enhances energy density without compromising taste, texture, or overall acceptability.
3. To determine optimal processing methods (drying, frying, baking) to enhance nutrient retention, extend shelf life, and increase energy content.
4. To conduct a nutritional analysis, focusing on protein, fat, carbohydrates, calories, and essential micronutrients.
5. To assess sensory attributes (taste, color, texture, aroma) through consumer testing and feedback.

Methodology:

The study begins with selecting fish species based on their nutritional profile, followed by recipe formulation. Processing methods, such as drying, frying, and baking, will be evaluated for their effects on nutrient retention and sensory characteristics. Nutritional analysis will be conducted using standardized laboratory techniques to measure macronutrients and micronutrients. Sensory evaluations will be carried out by a consumer panel rating taste, aroma, color, and texture. Shelf life and stability tests will assess the effects of storage on quality, and cost analysis will examine the feasibility of small-scale production.

Expected Outcomes:

The research aims to produce energy-dense, nutrient-rich fish chips that meet consumer standards for taste and texture. The optimized product is expected to offer health benefits, including a high protein-to-calorie ratio and essential micronutrients, with strong market potential. Cost analysis is projected to demonstrate small-scale production feasibility, making these fish chips accessible to local consumers.

Significance:

This study offers potential benefits for the snack food industry and public health by creating a nutritious, energy-dense alternative to conventional snacks. The research also supports sustainable fish utilization and highlights effective processing methods to preserve nutrients in fish-based snacks.

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