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Extraction of phenolic antioxidants from potato peel and development of a sustainable fish feed.

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A dissertation submitted in partial fulfilment of the requirements of the Bachelor of Science Honours Degree in Chemical Technology (HBSCCHT)

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APPROVAL FORM

The undersigned parties confirm they supervised, read, and endorse the Bindura University of Science Education for the acceptance of a research dissertation entitled:

Extraction of phenolic antioxidants from potato peel and development of a sustainable fish feed.

Submitted by Micah Mavhu

In partial fulfillment of the requirements for the Bachelor of Science Honors Degree in Chemical Technology.

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DECLARATION FORM

I, Mavhu Micah, the undersigned, certify to the Bindura University of Science Education that this dissertation is entirely original and that all scholarly sources used in it have been acknowledged and cited. Additionally, I certify that the current work has not been submitted for educational merit to any educational institution.

DEDICATIONS

My father, family, and friends are the ones to whom this masterpiece is dedicated; their unwavering financial and emotional support has been crucial to my goal of becoming a chemical engineer and technologist. I will always be grateful to you for believing in my goals and for your kind contributions, which made this accomplishment possible.

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ABSTRACT

As the cost of the conventional feed ingredients is increasing and, simultaneously, there is also the issue of discarding waste materials generated by the agro-industries, alternative fish feeds have been explored. In the present study, extraction of the phenolic antioxidants from the potato peel waste and develop a substitute feed for aquaculture was done. Potato peels were obtained, washed, dried in an oven at 60°C, ground into a fine powder, and subjected to the extraction of the phenolic antioxidants by using 70% ethanol. Total phenolic content was estimated by the ferric chloride colorimetric assay, and antioxidant capacity was estimated by using the hydrogen peroxide scavenging method with ascorbic acid as a standard. The Fourier Transform Infrared, X-Ray Diffraction, Thermogravimetric Analysis, and proximate analysis of the potato peel powder and the fish feed were performed. A remarkable content of phenolics was noticed in potato peel extract, with a total phenolic content of 8.47 milligram Gallic Acid Equivalent per gram and excellent antioxidant performance. The antioxidant capacity increased along with the concentration of the potato peel extract. The highest was 82.5% with hydrogen peroxide scavenging activity at the highest concentration. The presence of phenolic functional groups has been evidenced with Fourier Transform Infrared. The X-Ray Diffraction results suggest that the potato peel powder and the fish feed have an amorphous nature. TGA revealed good thermal stability for formulated feed. Proximate analysis revealed 35% crude protein, 6% crude fibre, 11,5% moisture, 6.4% ash, and 5.5% fat, which are desirable characteristics for growers' phase fish feed. This investigation has proven potato peel as a cost-effective, renewable, and

eco-friendly ingredient to provide phenolics, antioxidants, and other components that supplement the conventional ingredient to be used in the fish feed, and manage the waste from potato peels.

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KEY WORDS

1. Potato
2. Phenolics
3. Antioxidants
4. Protein
5. Fish Feed
6. Formulation

ABBREVIATIONS

1. PP- Potato Peel
2. PPW- Potato Peel Waste
3. TPC- Total Phenolic Content
4. GAE- Gallic Acid Equivalent
5. FFF- Formulated Fish Feed
6. TGA- Thermogravimetric Analysis
7. XRD- X-Ray Diffraction
8. FTIR- Fourier Transform Infrared

CHAPTER 1: INTRODUCTION

This chapter gives a background overview of the problem at hand and the proposed solution to the research.

1.1 Background

One of the fastest-growing food production sectors in the world, aquaculture greatly boosts employment, economic growth, and food security especially in developing countries. The use of potatoes in many different industries in processing leads to the production of a significant amount of waste. Peels, pulps, and starch from potatoes can be utilized as animal feed compositions (Ijaz et al., 2024).

Fish feed has a high price, which reaches 50–70% of the overall operating costs in intensive and semi-intensive aquaculture businesses. The higher prices of fish feed are the most significant barriers to sustainable growth (Saleem et al., 2025). However, there is a challenge to sustain aquaculture systems, especially in relation to feed formulation, which relies mainly on conventional materials like maize meal as the main ingredient of the fish feed and accounts for more than 60% of overall production expenses.

Currently, potato peels are being used for their primary low-value applications, such as animal feed (fish feed), fertilizer, or biogas production (Tripathi et al., 2025). Potato peels also contain many valuable components with antioxidant, antimicrobial, apoptotic, and anti-inflammatory properties. Studies have shown that potato peels contain high contents of dietary fibre, protein, carbohydrates, mineral matter, vitamins, phenolic, and antioxidants (Yuksel & Durmaz, 2022). The bioactive compounds present in potato peels (PP) are famous for possessing antioxidants, bactericidal, and bacteriostatic properties that have more benefits to human health. Additionally, potato peel has been used to produce several by-products such as bio-plastics, lactic acid, bio-composites, and nano-crystals (Awogbemi & Kallon, 2022). The phenolic compounds are more concentrated in potato skin than in nearby tissues (potato flesh) and decrease as one moves towards the middle of the potato

flesh or tuber. Phenolic acids are the most prevalent phenolic chemicals in potato peel, along with anthocyanins (B. Singh et al., 2020).

The processing of potatoes (*Solanum tuberosum L.*), one of the most extensively grown crops in the world, produces a large amount of waste, especially potato peels. Potato peels can make up as much as 15–40% of the weight of the tuber and are frequently thrown away or used inefficiently, which contributes to environmental pollution and disposal issues (Schieber, 2017). Potato peels are regarded as waste, but they consist of valuable bioactive compounds, particularly phenolic antioxidants like gallic acid, ferulic acid, caffeic acid, and chlorogenic acid, which show strong anti-inflammatory, antimicrobial, and antioxidant qualities (Vescovo et al., 2025).

In aquaculture practices, phenolic antioxidants are important for combating free radicals and reducing oxidative stress, which has a large impact on fish anatomy, immunological response, and growth performance (Abdel-Tawwab et al., 2022). Excessive stocking density, poor water quality, and imbalanced feed are some of the environmental stressors that may induce oxidative stress in fish, which lowers yield and raises the risk of disease. Thus, adding natural antioxidants to aquafeed has emerged as a key tactic to improve fish performance and resistance (Yousefi et al., 2021).

Phenolic compounds extracted from plants have been shown in many studies to enhance growth rate, feed conversion efficiency, immune response, and antioxidant enzyme activity in cultured fish species (Abd El-Naby et al., 2020). Nevertheless, despite the demonstrated antioxidant potential of potato peel phenolics, their application in aquaculture feed formulation is still largely unexplored, with most current studies concentrating on feed development and aquaculture sustainability (Jimenez-Champi et al., 2023).

Many methods, such as solvent extraction, ultrasound-assisted extraction, and microwave-assisted extraction, are effective for extracting phenolic antioxidants from potato peels. These extraction methods have been proven to affect yield and antioxidant activity (Vescovo et al., 2025). Optimization of extraction conditions is required to increase the recovery of phenolic compounds, while guaranteeing their stability and functionality for

incorporation into feed formulations. By transforming waste into products with added value, the utilization of these extracted antioxidants in aquafeeds is consistent with the ideas of sustainable agriculture and the circular economy. (Maksimenko et al., 2024).

The development of a potato peel-based diet boosted with phenolic antioxidants is an unusual and sustainable approach to aquaculture feeding. These feeds have the potential to improve fish health, reduce production costs, eliminate the need for expensive conventional ingredients, and reduce environmental contamination caused by agro-industrial waste. This work focuses on the extraction of phenolic antioxidants from potato peels and their application in the manufacture of a functional fish feed to support sustainable fish production.

1.2 Problem Statement

Aquaculture feed formulation continues to depend heavily on synthetic antioxidants such as BHT, BHA, and ethoxyquin, along with traditional ingredients such as rice bran and maize meal, to maintain feed stability and support optimal fish growth. Nonetheless, maize and rice bran compete directly with human food supplies, increasing feed costs and causing supply uncertainties. Additionally, synthetic antioxidants are under growing regulatory scrutiny and raise consumer safety concerns (Hu et al., 2025).

Potato peel, a plentiful agro-industrial by-product, serves as a promising natural alternative to aquafeeds due to its high phenolic content, which has strong antioxidant properties, and beneficial fiber and carbohydrate levels. Despite evidence that plant-based antioxidants can reduce lipid oxidation and oxidative stress in fish diets, the possibility of potato peel phenolic antioxidants fully replacing synthetic ones in fish feeds remains underexplored (Nayak et al., 2018).

Similarly, there is limited data on the viability of replacing maize meal and rice bran and partially reducing fishmeal with potato peel powder without compromising growth performance, feed efficiency, or fish health, even

though evidence shows that agro-industrial by-products can reduce cereal and fishmeal inclusion in aquafeeds (Gasco et al., 2018). This information gap constrains the use of potato peel derivatives as affordable, sustainable substitutes in fish feed formulations.

1.3 Aim of the Study

This study aims to extract phenolic antioxidants from potato peels and to develop a potato peel-based feed for sustainable aquaculture.

1.4 Objectives of the Study

- Extract phenolic antioxidant compounds from potato peels using solvent extraction.
- Determine the total phenolic content and antioxidant activity of the extracted compounds.
- Formulate an aquaculture feed that incorporates potato peel phenolic antioxidants.

1.5 Justification of the Study

This study is justified by the growing demand for sustainable aquaculture feeds and the urgent need to reduce dependence on conventional maize-based diets. Using leftover potato peels as a natural antioxidant source offers a creative way to address issues with environmental waste disposal and feed sustainability. Enhancing fish health and yields can be done cheaply and safely by extracting and adding phenolic antioxidants from potato peels. Additionally, by promoting the reuse of agro-industrial byproducts, the study supports the circular economy's foundations, supporting sustainable food systems and environmental preservation.

1.6 Significance of the study

The findings of this study are expected to contribute valuable knowledge to the fields of aquaculture nutrition, waste valorization, and sustainable agriculture. The developed potato peel-based feed may provide a practical alternative to conventional feeds, reducing production costs and improving fish health through natural antioxidant supplementation. By highlighting the potential of locally accessible agro-wastes in sustainable aquaculture feed development, the study is especially important for policymakers, feed producers, and small-scale fish farmers. The study may also lay the basis for future investigations into the common application of plant-based antioxidants in aquafeed formulations.

1.7 Delimitation of the Research

The extraction of phenolic antioxidants from potato peels and using them in a formulated aquaculture diet under laboratory or small-scale laboratory conditions is the only focus of this work. The study centers on phenolic chemicals rather than fully investigating other bioactive components of potato peels, like dietary fiber or glycoalkaloids.

CHAPTER 2: LITERATURE REVIEW

This chapter reviews the literature to contextualize investigations into using potato peel waste-derived powder and phenolic extracts as raw materials for the development of fish feed. The review will focus on these core areas: extraction of phenolic antioxidants from potato peels, determination of total phenolic content, antioxidant scavenging activity of phenolic extracts, characterization of potato peel powder, and existing knowledge on the utilization of potato peels in fish feed formulation.

2.1 Potato peel as an Agro-Industrial Waste

Large amounts of peel waste are produced by the potato processing industry when chips, fries, and other processed potato products are made. A sizeable amount of the overall weight of potatoes is made up of potato peel trash, which is frequently thrown away as garbage or utilized as cheap animal feed. However, research has revealed that the concentration of beneficial chemicals in potato peel is higher than in potato flesh (Akyol et al., 2024). One significant underutilized by-product stream from the potato processing industry is potato peel, which may contain useful bioactives like antioxidants (Martinez-Fernandez et al., 2021).

Currently, food consumption is less than food production, about 30-40% of

food wastage is generated, which, on many occasions, is disposed of in landfills or generates energy using incineration. The most popular foods in this context are fruits and vegetables, which are also quite polluting because of their high humidity and microbial loads. Additionally, the production of by-products is increased by the industrial processing of fruits and vegetables to create products like juices, jams, and frozen or dried goods (Rodríguez-Martínez et al., 2021).

Potato tubers (*Solanum tuberosum L.*) are the fourth most significant agricultural product, following wheat, rice, and maize. With a total production of 388 million in 2017, around 70% of this total production is processed in developed countries, resulting in a significant amount of potato peel waste (PPW) as a byproduct. Although the feed business considers PPW to be a zero-value by-product due to its fibrous nature, it is a cheap by-product in other recycling industries due to its high concentration of some intriguing nutrients, including polyphenols and glycoalkaloids. Several glycoalkaloids, including α-chaconine and α-solanine, have been chemically and physically identified in potatoes and Solanum species (Benkeblia, 2020).

Because of these important components, potato peel is becoming increasingly popular as a raw material for functional meals, natural antioxidants, and animal feed ingredients. The valorization of potato peel waste contributes to sustainable waste management and resource utilization (Mostafa et al., 2024). However, when potatoes are processed, they are peeled and not used to recover these by-products, generating a considerable amount of residues that could contribute to environmental and sanitation problems (Xu et al., 2022a).

Potato peel, a byproduct of the potato processing industry, is an extremely low-cost, valuable, and easily accessible raw material to produce economically important substances, as well as for value addition and product extraction, such as dietary fibers, biopolymers, natural antioxidants, and natural food additives. This by-product has a high nutritional potential and contains fiber and bioactive substances that have been found to have health advantages (Jimenez-Champi et al., 2023).

The potato peel is made up mostly of the outer periderm and the cortex, which are removed during the peeling process. The outer layer serves as a protective barrier for the tuber; therefore, these tissues contain rich nutrients and phytochemicals. According to studies, the peel contains more antioxidants than the inside flesh (Samotyja, 2019).

2.2 Phenolic compounds in potato peels

Phenolic chemicals are a broad category of secondary plant metabolites distinguished by the presence of hydroxyl groups connected to aromatic rings. These chemicals are vital in plant defense processes and greatly contribute to plant materials' antioxidant capabilities.

Potato peels contain a wide variety of phenolic compounds, mainly belonging to the phenolic acid group. The most identified phenolic compounds in potato peel include chlorogenic acid, caffeic acid, gallic acid, protocatechuic acid, ferulic acid, and p-coumaric acid (Rodríguez-Martínez et al., 2021). Peels from processing types were profiled, yielding extracts containing up to 1200 and 300 μM of total phenols and steroidal glycoalkaloids, respectively (Pacifico et al., 2024). One of the most difficult issues in the circular economy is recovering useful bioactive chemicals from the food industry's most underutilized byproducts. Potato peels are the most significant waste produced during potato processing. They may, however, be a source of useful bioactive substances, such as polyphenols, which can be employed as natural antioxidants. Currently, environmentally friendly supporting technologies and new types of non-toxic organic solvents for the extraction of bioactive substances can greatly increase the sustainability of these processes (Grillo et al., 2023).

In addition, potatoes are a rich source of minerals and vitamins B1, B3, and B6 (Zhang et al., 2018) . They also have a lower fat content (Bellumori et al., 2017). Previous findings have highlighted potatoes as a rich source of polyphenol compounds (Makori et al., 2022). The high content of phenolic compounds in potato tubers has been shown to contribute to approximately

58–82% of the total antioxidant activity (Makori et al., 2021). Phenolic compound-rich extracts can be used to preserve and fortify foods, replacing synthetic antioxidants that are harmful and carcinogenic (Kumari et al., 2017).

Potato peel has much more phenolic content than peeled potato flesh. The main chemical compounds identified are chlorogenic acid, caffeic acid, ferulic acid, p-coumaric acid, gallic acid, vanillic acid, flavonoids, and anthocyanins (particularly in colored potatoes). Chlorogenic acid is frequently identified as the primary phenolic acid in potato peel, accounting for a significant portion of total phenolics (Xu et al., 2022a). These chemicals are useful because they reduce lipid oxidation, scavenge free radicals, slow deterioration, and protect biological tissues from oxidative stress.

2.3 Antioxidant activity of potato peel extracts

Potato peel extracts earned a lot of scientific attention due to their high antioxidant activity and phenolic chemical content. Potato peels, which are typically discarded as agro-industrial waste, have higher antioxidant contents than the edible flesh of the potato. These antioxidants, especially phenolic acids, flavonoids, and anthocyanins, can scavenge free radicals, limit lipid oxidation, and protect biological systems from oxidative stress (Rodríguez-Martínez., Gullón & Yáñez 2021).

The phenolic content of potato peel extracts is mostly responsible for their antioxidant properties. Chlorogenic acid, caffeic acid, ferulic acid, gallic acid, and p-coumaric acid are some of the main substances found. Because of its superior ability to scavenge radicals, chlorogenic acid is frequently the predominant phenolic component. These substances neutralize unstable reactive oxygen species (ROS) before they harm lipids, proteins, or DNA by giving them hydrogen atoms or electrons. (Joly et al., 2020). Potato peel phenolic extracts were successful in reducing oxidative reactions and showed strong free radical scavenging activity. Additionally, their research demonstrated the protective benefits of extracts against enteric viruses, indicating multifunctional bioactivity beyond antioxidant performance (Silva-

Beltrán et al., 2017).

In the same way, (Samotyja, 2019) studied potato peel extracts made using ethanol and water solvents and discovered that ethanolic extracts outperformed aqueous extracts in terms of antioxidant efficacy. This resulted from a higher concentration of polyphenolic chemicals being removed by ethanol. Potato peel extracts have the potential to be used as natural preservatives in food and feed formulations, according to the author, who also observed that they successfully postponed oxidation in lipid-containing food model systems.

When compared to several fruits, grains, and vegetables, the antioxidant activity of potato by-products was found to be extremely high, with ORAC values ranging roughly from 1500 to 1650 μM Trolox equivalents per gram in various fractions. Additionally, the study discovered an important beneficial correlation between antioxidant capacity and total phenolic content, demonstrating that phenolic chemicals are the main drivers of antioxidant performance (Joly et al., 2020).

Because of their anthocyanin concentration, colored potato peels have demonstrated even more antioxidant activity than white potato cultivars. Ten colored potato peel varieties were examined in a food chemistry study, and the results showed that all hydroethanolic extracts had antioxidant activity, with pigmented cultivars exhibiting especially potent benefits. The extracts' total antioxidant capacity was greatly enhanced by anthocyanins such as pelargonidin, peonidin, and malvidin (López-Cruz et al., 2021).

The extraction method also affects antioxidant yield. Advanced techniques, including heating-assisted extraction and ultrasound-assisted extraction, frequently improve the recovery of phenolic antioxidants. However, the conventional solvent extraction employing ethanol-water combinations is still widely used. While ultrasound increases solvent penetration through cavitation effects, heat treatment can promote the release of bound phenolics from cell wall structures. To maximize antioxidant activity from potato peel biomass, process optimization is crucial (Xu et al., 2022a).

Antioxidant-rich potato peel extracts may have useful applications in aquaculture and animal nutrition. Fish growth, immunity, and reproduction can all be negatively impacted by oxidative stress. The addition of natural antioxidants to feed may increase fish health, decrease oil rancidity, and improve feed stability. Potato peel extracts are a sustainable substitute for synthetic antioxidants like BHT and BHA because they are inexpensive and made from waste biomass (Rodríguez-Martínez et al., 2021).

Antioxidant activity can differ based on cultivar, storage circumstances, drying technique, solvent type, and extraction parameters, regardless of its potential. Phenolic concentration may be lowered by lengthy storage or exposure to extreme heat. For industrial applications, regulation of raw materials and extraction procedures is therefore essential.

2.4 Extraction of phenolic compounds from potato peels

When recovering phenolic chemicals from plant sources, extraction is a crucial step. To increase the effectiveness of recovering phenolic compounds from potato peel, several extraction methods have been developed. One common agro-industrial by-product produced when potatoes are processed into chips, fries, starch, and dehydrated items is potato peels. Potato peel is a crucial raw material for value-added extraction procedures due to its potent antioxidant, antibacterial, and anti-inflammatory qualities (Rodríguez-Martínez et al., 2021).

Potato peel phenolic compounds serves as organic defense agents against pathogenic infections and environmental stress. These chemicals must be extracted to be recovered in a form that can be used because they are embedded in plant cell wall structures. Particle size reduction, temperature, extraction time, pretreatment conditions, and solvent choice all affect the effectiveness of an extraction (Joly et al., 2020).

2.4.1 Preparation of potato peels for extraction

Potato peels are often thoroughly cleaned to remove dirt, dust, and impurities before extraction. After cleaning, the peels are either vacuum-dried, freeze-dried, hot-air oven-dried, or sun-dried. Drying increases storage stability, lowers moisture content, and stops microbial deterioration. Although excessive heat may degrade some phenolics, oven drying at moderate temperatures (40–60°C) is frequently utilized since it is simple and cheap (Mushtaq et al., 2023). The peels are ground into a powder after drying to enhance mass transfer and surface area during extraction. Better intracellular phenolic release and improved solvent penetration became a possibility due to the use of smaller particle sizes.

2.4.2 Conventional solvent extraction

Phenolic compounds are mostly recovered from potato peels using conventional solvent extraction. It involves integrating peel powder with an appropriate solvent while stirring for a specific period. Common solvents include ethanol, methanol, acetone, water, ethanol-water mixtures, and methanol-water mixtures. Aqueous ethanol is often selected among these as it is less hazardous, safe for food, and efficient at removing polar phenolic chemicals. Ethanol-water combinations provide higher total phenolic yields than water alone, according to (Samotyja, 2019). Since many phenolic acids are polar, solvent polarity is crucial. To create concentrated extracts, the extraction procedure usually involves soaking the powder in a solvent for several hours at either room temperature or a higher temperature (30–60°C), followed by filtration and solvent evaporation.

2.4.3 Ultrasound-Assisted Extraction (UAE)

Because ultrasound-assisted extraction is efficient and requires less processing time, it has gained popularity. Plant cell walls are ruptured by cavitation bubbles that are created in the solvent by ultrasound vibrations. As a result, bound phenolic chemicals are more easily released, and solvent penetration is improved. Xu et al., (2022a) found that ultrasound-assisted

extraction significantly improved phenolic yield from potato peel waste compared with conventional shaking extraction. Additional advantages include lower solvent consumption, shorter extraction time, and operation at lower temperatures, which helps preserve heat-sensitive antioxidants.

2.4.4 Microwave-assisted extraction (MAE)

In microwave-assisted extraction, moisture inside plant tissues is quickly heated by microwave energy, which builds up internal pressure and ruptures cells. As a result, phenolics diffuse into the solvent more quickly. MAE has several benefits. High extraction efficiency, quick extraction times, less solvent usage, and better intracellular chemical recovery. However, if power and time are not appropriately controlled, overheating could lead to the deterioration of sensitive chemicals.

2.4.5 Enzyme-assisted extraction

In the cell wall of plants, phenolic chemicals can occasionally bind to structural polysaccharides. Cellulase, pectinase, hemicellulase, or amylase are used in enzyme-assisted extraction to break down these structures and liberate bound phenolics (Lalas et al., 2026). Because it may utilize fewer solvents and increase extraction efficiency in moderate conditions, this approach is regarded as environmentally benign (Thi et al., 2024).

2.4.6 Factors affecting extraction yield

Several factors influence the recovery of phenolic compounds from potato peels:

2.4.6.1 Solvent type and concentration

Since the solubility of phenolic compounds varies according to their chemical structure, the most important consideration is the choice of solvent. As phenolics are often polar, polar solvents such as ethanol, methanol, or aqueous mixes work better than non-polar ones (Ismail et al., 2024).

2.4.6.2 Temperature

Excessive temperatures can destroy phenolics, so moderate heating is preferred as it increases diffusion and solubility (Nisca et al., 2022).

2.4.6.3 Extraction time

Extended contact time enhances recovery until equilibrium is reached, at which point oxidation or deterioration may occur (Ismail et al., 2024).

2.4.6.4 Particle size

Smaller particles improve extraction efficiency and surface area. Higher yields of bioactive chemicals such as flavonoids and phenolic acids are strongly correlated with faster mass transfer and improved solvent penetration made possible by a reduction in particle size (Farooq & Yu, 2024).

2.4.6.5 Drying method

Freeze-dried peels can retain more phenolics than oven-dried peels. The best technique for maintaining phenolic content and antioxidant activity in a variety of plant materials, including potato derivatives and other fruits and vegetables, is typically freeze-drying (Calín-Sánchez et al., 2018.; Coşkun et al., 2024). Chemical and physical integrity of the plant matrix can be maintained effectively by freeze-drying (Coklar et al., 2018).

2.4.6.6 Variety of potato

White or bright-fleshed potatoes are found to contain phenolic compounds, which are less than those of the colored ones (purple-fleshed and red-fleshed). Studies have shown that phenolic compounds found in colored potatoes are almost three times those of white potatoes (Lee et al., 2016; Cebulak et al., 2022).

2.5 Determination of total phenolic content

An essential first step in assessing the antioxidant capacity of plant extracts is determining the total phenolic content (TPC). Phenolic chemicals in plant extracts are measured using a variety of analytical techniques.

2.5.1 Determination of total phenolic content (TPC) using the Folin-Ciocalteu (FC) method.

The Folin-Ciocalteu reagent is a common spectrophotometric technique used to measure the total phenolic content of potato peels. It works by transferring electrons from phenolic compounds to phosphomolybdic/phosphotungstic acid complexes in an alkaline solution (Joly et al., 2020). When reduced by phenolate ions, the phosphomolybdic/phosphotungstic acid combination takes on a vivid blue color. In its oxidant form, it appears yellow. The process of color creation relies on the transfer of electrons to reduce the acid complex and form chromogens with lower-valence metals (Raposo et al., 2024).

2.5.1.1 Procedure of the Folin-Ciocalteu assay.

In a typical laboratory method, an aliquot of the sample extract is mixed with diluted Folin-Ciocalteu reagent. The initial reaction is allowed to proceed for 3 to 8 minutes, after which a sodium carbonate solution is added to create alkaline conditions. After incubation for 30 to 60 minutes at either room temperature or 40°C, absorbance is measured at 765 nm using a UV-Vis spectrophotometer. Standard gallic acid solutions are used to construct a calibration curve, and the regression equation is used to determine TPC (Lucas et al., 2022; Rizvi et al., 2023). The results are then expressed as gallic acid equivalents.

2.5.2 Determination of total phenolic content using ferric chloride ($FeCl_3$)

The ability of phenolic compounds to form persistent, brightly colored complexes with iron ions forms the basis for the calorimetric assay used to determine total phenolic content using ferric chloride (Jantra et al., 123 C.E.).

Due to their speed, affordability, and high sensitivity to ortho-hydroxyphenolic chemicals, $FeCl_3$-based assays are becoming increasingly popular (Samotyja, 2019).

2.5.2.1 Principles of the $FeCl_3$ assay

This assay entails the interaction of phenolic hydroxy groups, specifically ortho hydroxyl groups, with Fe^{3+} salts (Suslavich et al., 2024). A color change is observed, usually brownish-green or black-blue, and is observed spectrophotometrically (Zahra Siddiqui et al., 2017). The intensity of the color produced is proportional to the concentration of phenolic compounds present in the extract (Singh et al., 2019).

A UV-visible spectrophotometer can be used to measure the colorful complex that results from the reaction between the plant extract and an aqueous ferric chloride solution in this test. Depending on the experimental conditions, the absorbance of the solution is often measured at wavelengths between 700 and 760 nm (Akyol et al., 2021). A calibration curve is created using standard solutions of gallic acid at various concentrations, usually between 20 and 200 µg/mL, to measure the phenolic content. The calibration curve is then used to determine the extract's phenolic content, which is then represented as milligrams of gallic acid equivalents per gram of dry material (mg GAE/g) (Akyol et al., 2016).

2.6 Evaluation of antioxidant activity of phenolic compounds

Among the most significant naturally occurring antioxidants are phenolic compounds, which are found in plant materials such as fruits, vegetables, grains, and agro-industrial wastes such as potato peels. Their capacity to donate hydrogen atoms or electrons, bind metal ions, and neutralize free radicals accounts for most of their antioxidant action. Several in vitro tests are frequently performed to assess the antioxidant activity of phenolic compounds because no single technique can adequately characterize antioxidant behavior (Apak et al., 2016).

2.6.1 DPPH radical scavenging assay

One of the most used techniques for determining free radical scavenging activity is the DPPH (2,2-diphenyl-1-picrylhydrazyl) assay. When antioxidants reduce DPPH, a stable purple radical, it turns yellow. At 517 nm, the absorbance reduction is observed. Stronger antioxidant potential is indicated by higher scavenging activity. This test works well with phenolic extracts and is quick and easy (Sridhar & Charles, 2019; Florescu et al., 2024).

2.6.2 ABTS radical cation decolorization assay

Antioxidants diminish the blue-green $ABTS^{+}$ radical cation used in the ABTS test. Spectrophotometric measurements of the color intensity decrease are made at 734 nm. ABTS is appropriate for hydrophilic and lipophilic phenolics because, compared to DPPH, it works well in both aqueous and organic systems (Sadeer et al., 2020).

2.6.3 Ferric reducing antioxidant power (frap) assay

The FRAP assay evaluates a phenolic compound's capacity to convert ferric ions (Fe^{3+}) to ferrous ions (Fe^{2+}). At 593 nm, a blue ferrous-tripyridyltriazine complex is formed. Greater reducing power is indicated by higher absorption. It is easy to use, reasonably priced, and can be applied to food extracts (Bălăşoiu et al., 2023; Knez et al., 2025).

2.6.4 Hydrogen peroxide (H_2O_2) scavenging assay

The ability of phenolic compounds to neutralize hydrogen peroxide, which can produce hydroxyl radicals in cells, is measured by this experiment. A decrease in the peroxide concentration indicates the antioxidant activity of the phenolic compounds. For extracts meant for biological purposes, it is very helpful (Rigneault et al., 2025).

2.7 Application of potato peel in aquaculture feed

A significant agro-industrial by-product of potato processing, potato peels have drawn interest as an affordable and sustainable component of aquaculture diets. Carbohydrates, dietary fiber, moderate protein, minerals (especially calcium and phosphorus), and bioactive compounds such as

phenolics, in potato peels, can support fish growth and health when properly processed and included at suitable levels. Their use aligns with circular economy principles by converting food waste into valuable feed resources (Sampaio et al., 2020; Vescovo et al., 2025).

2.7.1 Energy source in fish diets

Because potato peels are high in starch and easily digested carbohydrates, fish that are both herbivorous and omnivorous, such as tilapia, carp, and catfish, can benefit from using them as an energy source. Potato peel meal can lower feed costs while preserving dietary energy balance when used in place of certain maize or wheat bran. This aids in preserving protein for development as opposed to energy metabolism (Saleem et al., 2025).

2.7.2 Partial replacement of conventional feed ingredients

One of the main uses for potato peels is to partially replace costly traditional ingredients like wheat middlings, rice bran, or maize. Low-cost substitutes such as potato peels are economically advantageous because feed accounts for 50–70% of aquaculture production costs. Moderate inclusion levels can support adequate growth performance, according to studies (Saleem et al., 2025b).

2.7.3 Source of functional fiber for gut health

When utilized in small amounts, potato peels' soluble and insoluble dietary fiber may enhance intestinal microbial balance, digestion, and gut motility in certain fish species. However, inclusion needs to be maximized because too much fiber can decrease nutrient digestion (Sampaio et al., 2020).

2.7.4 Natural antioxidant source

Phenolic compounds such as flavonoids, caffeic acid, and chlorogenic acid are prevalent in potato peels. These substances have antioxidant action, which improves fish immunity, flesh quality, and feed shelf life while lowering oxidative stress. Thus, extracts from potato peels can be utilized as useful additions in aquafeeds (Sampaio et al., 2020).

2.7.5 Growth performance enhancement

Low inclusion levels (about 5%) of potato peel meal in fish diets were found to promote weight gain, feed conversion ratio (FCR), and specific growth rate

(SGR) in fingerlings of *Labeo rohita* when compared to greater inclusion levels. This implies that, when used sparingly, potato peels may be advantageous (Saleem et al., 2025).

2.7.6 Environmental sustainability

Utilizing potato peels in aquaculture feed reduces reliance on fishmeal and cereal grains while also reducing disposal issues from the potato-processing industries. This promotes resource efficiency, decreases waste, and lowers feed costs, all of which support sustainable aquaculture (Vescovo et al., 2025d).

2.8 Characterization of potato peel powder and potato peel fish feed.

To determine the structural traits, thermal stability, chemical composition, and nutritional quality of potato peel powder and formulated potato peel fish feed, characterization is essential. Analytical methods such as X-ray Diffraction (XRD), Thermogravimetric Analysis (TGA), Fourier Transform Infrared Spectroscopy (FTIR), and proximate analysis are widely utilized to evaluate organic waste-derived feed ingredients and formulated aquafeeds. The suitability of potato peel powder as a sustainable feed additive or ingredient is assessed using these techniques (Mushtaq et al., 2024).

2.8.1 Fourier Transform Infrared Spectroscopy (FTIR)

The technique called FTIR is used for examining the chemical composition of potato peel powder, potato peel extract, and formulated fish feed. It shows the functional groups present in the extract, powder, and feed, including hydroxyl (-OH) and carbonyl (C=O). FTIR has been used to analyze the chemical composition of potato peels, indicating the presence of cellulose, starch, and hemicellulose (Espinoza-García et al., 2023).

2.8.2 X-Ray Diffraction (XRD)

X-Ray diffraction (XRD) serves as a primary analytical tool to investigate the long-range crystalline order and polymorph structures of polysaccharides (starch and cellulose) within agro-industrial by-products (Montoya-Escobar et al., 2022). Native starches are semi-crystalline granules consisting of

alternating amorphous regions (composed of amylose and branched amylopectin points). When reviewing potato (Solanum tuberosum) residues and peels, XRD analysis typically isolates the distinct B-type crystalline pattern (Dong et al., 2022). This structure is chemically characterized by a more open hexagonal unit cell capable of accommodating standard water molecules within its core lattice.

2.8.3 Determination of mycotoxins

Since the cost-effective and plant-based raw material sources are included in the aquaculture diet, the appearance of animal feed contaminants might influence the quality and safety of aquafeeds under certain circumstances. Mycotoxins are toxic metabolites with low molecular weight from some fungi, and frequently exist in plant-based feedstuff and have been identified as common feed contaminants in aquaculture feed. The contamination of mycotoxins would result in massive mortality, reduced feed efficiency, and increased disease susceptibility, and it is very important to monitor the contamination of mycotoxins promptly in aquaculture (Vardali et al., 2023a). The most frequent mycotoxins identified in feeds for aquaculture consist of aflatoxins, Fumonisin, ochratoxins, trichothecenes, and zearalenone. Mycotoxins are synthesized by molds of the genus *Aspergillus*, *Fusarium*, and *Penicillium*. The presence of mycotoxins in fish feeds has caused many worries since mycotoxins can negatively influence the growth, the immune response, and the functions of several organs and tissues in the fish, in the reproduction processes, as well as in the survival of fish.

CHAPTER 3: MATERIALS AND METHODS

Analytical reagent (AR) grade chemicals and reagents were used in the investigation. Since the supplied materials' purity satisfied experimental requirements, they were used exactly as they were received, requiring no further purification. To prevent ultraviolet (UV) light-induced degradation, all stock solutions and samples were kept in amber reagent bottles, with the

amber glass acting as an efficient UV shield. To minimize possible exposure, solution preparation and handling were done in a fume hood, and all experimental procedures used only deionized water.

Sample collection, pretreatment, solvent extraction, quantitative phytochemical determination, powder characterization, feed formulation, and quality evaluation were all part of the experimental strategy. To guarantee consistency, analytical dependability, and conformity to food-grade laboratory standards, every step was carefully put together.

3.1 Material and equipment

Fresh Irish potato peels (PP), NaOH; HCl; Deionized water; Ferric Chloride; H_2O_2; Ascorbic acid; Potassium dihydrogen phosphate; Gallic acid; Wheat bran; Wheat Flour; Soybean Oil; Fish Meal; Soybean Meal; Vitamin and Mineral premix; Methionine; Lysine; Phenolic Antioxidants; Oven; Pestle & Mortar;

Analytical balance; UV–Vis Spectrophotometer; FTIR spectrometer; Soxhlet apparatus; Kjeldahl digestion setup; Sieves (250 µm); Filter Papers; Buchner Funnel; Volumetric Flasks; Amber Bottles; Mixer

3.1.1 Optimized pretreatment of potato peels

Fresh potato peels were collected from a nearby fast-food outlet in Bindura, sorted to remove any unwanted or broken material, and transported to the lab in sanitized plastic zip bags. After collection, the peels were rinsed with deionized water to remove any remaining impurities and then carefully cleaned under running tap water. The peels were cut into smaller pieces and then dried for 48 hours at 50 °C in a hot-air oven until their weight remained consistent. After drying, the material was crushed into a fine powder using a pestle and mortar and sieved through a 250 µm mesh screen to achieve a consistent particle size. The resulting potato peel powder was stored at room temperature in an airtight plastic zip bag until needed for further analysis.

3.1.2 Extraction of phenolic antioxidants from potato peels

10 g of powdered dry potato peel was weighed and placed in a 250 mL conical flask. 100 mL of 70 % ethanol (1:10 w/v) was added, and the flask was sealed with aluminum foil. The mixture was placed on an orbital shaker overnight. After shaking overnight, the mixture was filtered using vacuum filtration to obtain the filtrate (Riciputi et al., 2018; Joly et al., 2020). The filtrate was centrifuged at 4000 rpm for 10 minutes. The supernatant (phenolic antioxidant extract) was decanted and transferred to an amber container. The extract was labeled and stored at 4 °C.

3.1.2.1 Preparation of solutions

1 % $FeCl_3$ solution was prepared by dissolving 1 g of $FeCl_3$ in 100 mL of deionized water. 1 g of $FeCl_3$ was weighed using an analytical balance. The weighed $FeCl_3$ was transferred into a 100 mL beaker. 70 mL of deionized water was added to the 100 mL beaker containing 1 g of $FeCl_3$. A rod was used to stir the mixture until completely dissolved (Apostică et al., n.d.; Athipornchai & Klangmanee, 2021). The solution was transferred into a 100 mL volumetric flask using a funnel. The volume was made up to the 100 mL mark with deionized water and mixed thoroughly.

100 mg of gallic acid was accurately weighed into a 100 mL beaker and transferred into a 100 mL volumetric flask. A small volume of deionized water was used to dissolve gallic acid and made up to the 100 mL mark with deionized water, thus 1 mg/mL stock. Working standards from 20 to 100 µg/mL were prepared by serial dilution. 20 mL of stock solution was pipetted into a 100 mL volumetric flask, and up to the 100 mL mark was made with deionized water (Michiu et al., 2022).

3.1.3 Estimating total phenolic content using the ferric chloride ($FeCl_3$) colorimetric assay

1 mL of potato peel extract was pipetted into a test tube. 1 mL of 1 % $FeCl_3$ solution was added, and 8 mL of deionized water was added. The mixture was mixed thoroughly, then allowed to stand at room temperature for 10 minutes, and the color change was observed to be greenish-black, which shows the presence of phenolics. The absorbance was measured at 760 nm using a UV-Vis spectrophotometer (Thermo Scientific Genesys 10S UV-Vis). A gallic acid calibration curve was prepared. The findings of the extract's total phenolic content were expressed as gallic acid equivalent per gramme dry weight of the sample (GAE/gw) (Kumar et al., 2017). The total phenolic content of the potato peel extract was calculated using a gallic acid calibration equation and expressed as milligrams of gallic acid equivalent per gram of dry peel (mg GAE/g) using equation 3.1:

$$\text{TPC (mg GAE/g)} = \frac{C \times V}{m} \qquad (3.1)$$

Where: c is concentration obtained from calibration curve, v is volume of extract, and m is mass of dry potato peel used for extraction.

3.1.4 Hydrogen peroxide scavenging assay

The H_2O_2 technique was used to assess the antioxidant activity of potato peel phenolic extract. 0.6 mL of 40 mM H_2O_2 and 3.4 mL of 0.1 M phosphate buffer were added to 0.1 mL of the sample. This combination was incubated at room temperature for ten minutes (Gupta et al., 2022). Following incubation, absorbance was measured at λmax 230 nm in comparison to a blank solution. The standard used was ascorbic acid. The percentage of H_2O_2 scavenging

was determined using equation 3.2:

$$\% \text{ scavenged } (H_2O_2) = \frac{A_{sample}\text{-}A_{control}}{A_{sample}} \times 100 \quad (3.2)$$

3.1.5 Feed formulation and preparation of 1 kg potato peel fish feed incorporating phenolic extracts from potato peel.

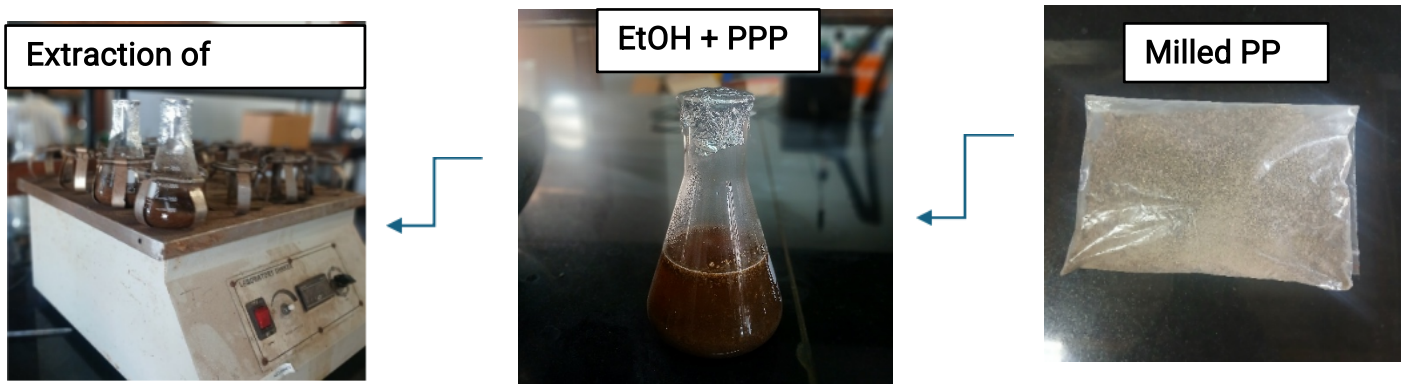
Table 3.1: Feed ingredient composition (1 kg)

Ingredient	Amount (g)	Percentage (%)
Fishmeal	300	30.0
Soybean meal	420	42.0
Wheat bran	108	9.0
Wheat flour	70	7.0
Potato peel powder	40	4.0
Soybean oil	30	3.0
Vitamin–mineral premix	20	2.0
Methionine	5	0.5
Lysine	3	0.3
Mycotoxin binder	2	0.2
Potato peel phenolics	2	0.2
Total	1000	100

To achieve a total batch mass of 1 kg, each ingredient was carefully weighed exactly as in table 3.1 above. In a clean mixing vessel, fishmeal, soybean meal, wheat bran, wheat flour, potato peel powder, mycotoxin binder, lysine, methionine, and the vitamin-mineral premix were mixed until a homogeneous mixture was obtained (Ajani et al., 2016). To ensure uniform dispersion, the potato peel phenolic extract was first dissolved in a tiny amount of deionized



water. It was then gradually sprayed into the dry materials while being continuously mixed. Enough warm deionized water was added after vegetable oil was progressively added to create a cohesive, hard dough ideal for pellet production. To create pellets of uniform size, the produced dough was manually extruded using a pelletizer (Okolie et al., 2019; Nenciu et al., 2022). For 24 hours, the pellets were dried at 60 °C in a hot-air oven until their weight remained constant. The pellets were then cooled to ambient temperature and kept in airtight containers at 4 °C until needed again. Wheat flour served as a binding agent in the composition (Onuoha, 2018; Karim et al., 2024a). Phenolic extract from potato peels was used as a natural source of antioxidants. Heat-sensitive bioactive molecules were preserved by drying at comparatively low temperatures. While the potato peel phenolic extract (2 %) offered a concentrated dose of natural antioxidants, the potato peel powder (4 %) provided dietary fiber, carbs, and leftover phytochemicals. (Fig 3.1) shows the extraction of phenolic compounds and feed formulation



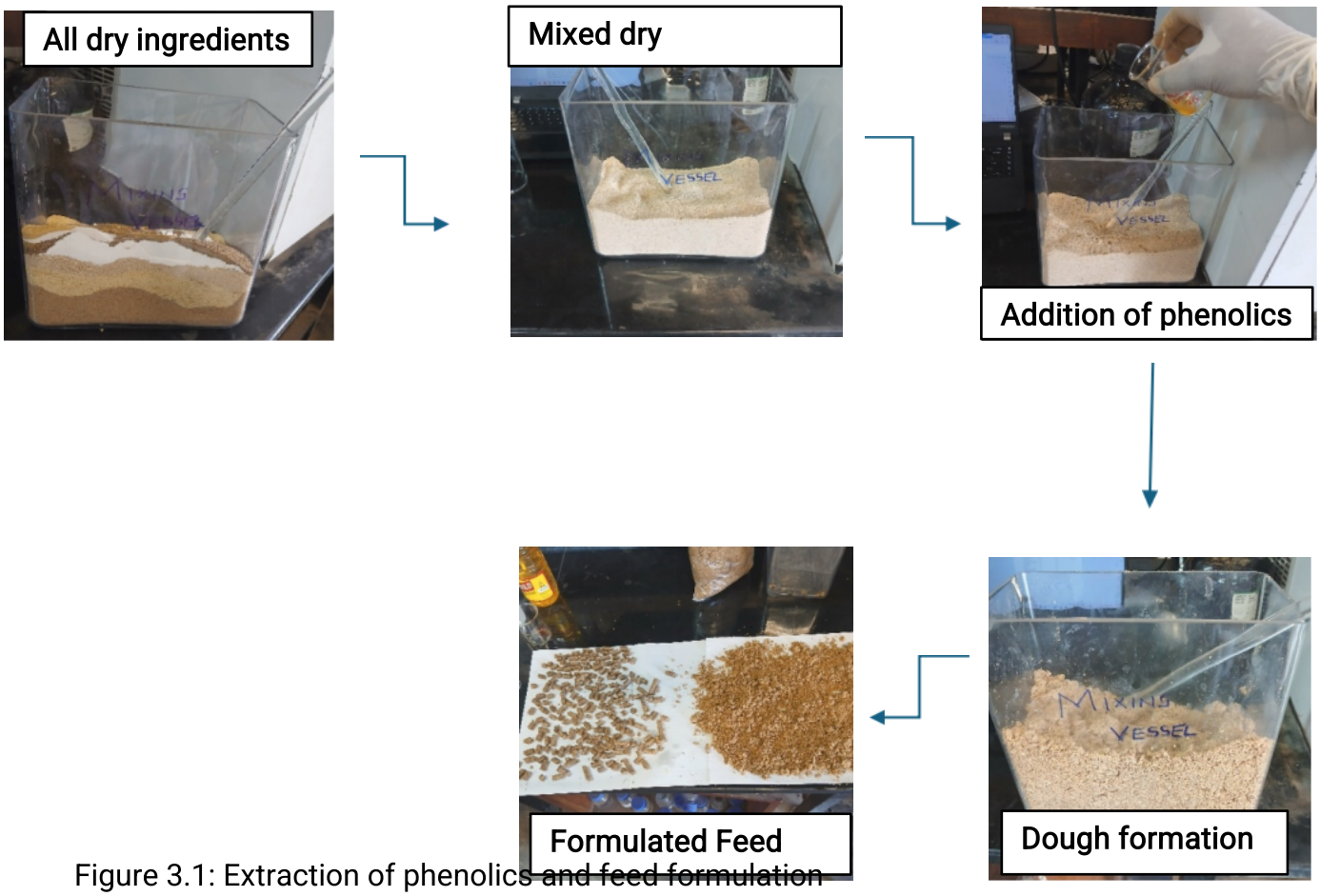


Figure 3.1: Extraction of phenolics and feed formulation

3.2 Characterization

3.2.1 Fourier Transform Infrared Spectroscopy (FTIR) Analysis

The PPP and FFF were finely ground and made into a KBr pellet, sterilized with alcohol before analysis using a spatula. The reading was taken from 4000 to 400 cm^{-1} wavelengths (Tripathi et al., 2025b). The functional groups linked to phenolic compounds in the potato peel extract, potato peel powder, and formulated fish feed were identified using FTIR (IR SpiritQatri-s Shimadzu). To verify the presence of phenolic functional groups, the obtained spectra were interpreted by comparing distinctive absorption regions with conventional reference spectra.

3.2.2 X-ray diffraction (XRD) Analysis

Dried potato peel powder and the formulated feed mash were finely ground using a laboratory mortar and pestle. The resulting powders were sieved through a 250 µm mesh to obtain a uniform particle size before analysis. X-ray diffraction of potato peel powder and formulated fish feed was studied for its crystalline and amorphous structural features using an X-ray diffractometer (Brucker D2 PHASER 2^{nd} generation, Brucker AXS, USA). The analysis was conducted at room temperature using Cu Kα radiation (wavelength 0.154 nm), operated at 40 kV and 30 mA. The range of the

angular region was 20 Θ – 100 Θ (Tripathi et al., 2025b). This technique was used to determine the degree of crystallinity, a parameter that affects the solubility, digestibility, and stability of bioactive constituents in aquaculture feeds. The diffraction profiles were examined to distinguish crystalline peaks from amorphous regions. Phase identification and structural interpretation were achieved by comparing the observed peak positions and intensities with standard reference patterns. The degree of crystallinity was estimated by calculating the ratio of the crystalline peak area to the total area of the diffractogram. Using equation 3.3:

$$\% CI = \frac{I_{200} - I_{am}}{I_{200}} \times 100 \quad (3.3)$$

3.2.3 Thermogravimetric analysis (TGA)

Dried potato peel powder and ground formulated fish feed pellets were used for TGA analysis (Adedeji et al., 2020; Chen et al., 2021). Each sample was finely powdered and stored in desiccators before analysis to prevent moisture absorption. Thermogravimetric analysis was performed using a thermogravimetric analyzer (Discovery TGA 550 TA Instruments, New Castle, Delaware, USA). 10 mg of each sample was placed in a platinum crucible and heated from 25 °C to 700 °C at a constant heating rate of 10 °C/min under a nitrogen atmosphere to prevent oxidative degradation (Tripathi et al., 2025b). The change in sample mass was continuously recorded as a function of temperature. Thermogravimetric (TG) curves were analyzed to determine the temperature ranges of mass loss, maximum degradation temperatures, and residual mass (char yield).

3.3 Proximate analysis

3.3.1 Determination of crude proteins

The formulated fish feed samples were finely ground and dried to constant weight before analysis. Approximately 0.5 g of dried sample was weighed into a Kjeldahl digestion flask. 10 mL of concentrated sulfuric acid and 1 g of catalyst mixture were added. The mixture was heated until the solution became clear, indicating complete digestion (Mæhre et al., 2018). The digested sample was allowed to cool and diluted with distilled water. The digested solution was made alkaline by adding 40 % sodium hydroxide. The liberated ammonia was distilled into 25 mL of 4 % boric acid solution containing a mixed indicator. The trapped ammonia was titrated with 0.1 N hydrochloric acid until the endpoint was reached (Kozin et al., 2022). Calculated the percentage of crude protein using equation 3.4:

$$\text{Nitrogen}\ (\%) = \frac{V \times N \times 14.01}{W} \times 100 \quad (3.4)$$

Crude Protein (%) = Nitrogen (%)×6.25

Where:

V = Volume of HCl used (mL)

N = Normality of HCl

W = Weight of sample (mg)

3.3.2 Determination of fat by the Soxtherm machine

3 pre-dried boiling stones were placed in the extraction beakers, then the extraction beaker was weighed, and its value was recorded. (Pre-dried boiling stones in a desiccator for 1 hour). 5 g of ground sample was accurately weighed, it was enclosed in filter paper, and was placed into a porous thimble. A piece of cotton was placed and pressed into the thimble. This allows distribution of the solvent as it drops onto the sample, and it also ensures that the filter paper does not fall out. the thimble was placed on the wire holder and was placed in the extraction beakers; 150 mL of hexane was poured into each extraction beaker. The pressure pump was switched on, running water, and the Soxtherm machine (SOX 416 S/N 8465 18 0151) (Computer and the extraction chamber). the Soxtherm Manager Program was opened, and the safety key was put in place. the pressure on the Soxtherm Manager Program display was checked ; the pressure should range between 4.4 and 4.6 bars. The pressure was adjusted accordingly on the pump if out of range. The extraction beakers were placed in the extraction chamber. the Petroleum Ether program was selected and ran. The program should run for 2 hours and 32 minutes. The extraction beakers were carefully disconnected from the extraction chamber after 2 hours and 32 minutes and the wire stands and thimble were removed. The extraction beaker was reconnected to the extraction chamber. The dry flask program was selected and ran. The program should run for 17 minutes. Once the program ended, the beakers were removed and placed in a desiccator to cool. (Official Methods of AnalysisSM Program - AOAC INTERNATIONAL, n.d.) The beaker weighed to record its value and used it to calculate the percentage of oil in the sample using Equation 3.5:

$$\% \text{ of oil}_{\text{initial sample}} = \frac{m_2 - m_1}{m_0} \times 100 \quad (3.5)$$

M1: weight (g) of the empty extraction beaker with boiling stones

M2: weight (g) of the extraction beaker with fat after the drying process

M0: sample weight (g)

3.3.3 Determination of crude fiber

The final feed pellets were finely ground and defatted before analysis to avoid interference from lipids. Defatting was achieved using petroleum ether in a Soxhlet extractor. Approximately 2.0 g of defatted sample was weighed into a digestion flask. 200 mL of 1.25 % sulfuric acid was added, and the mixture was heated under reflux for 30 minutes. The residue was filtered and washed with hot distilled water until acid-free. The residue was transferred back into the flask, and 200 mL of 1.25 % sodium hydroxide was added. The mixture was again heated under reflux for 30 minutes. The residue was filtered, washed thoroughly with hot water, and transferred to a pre-weighed crucible. The crucible containing the residue was dried in a hot air oven at 105 °C to constant weight (W_1). The dried residue was incinerated in a muffle furnace at 550 °C for 3 hours. The crucible was cooled in a desiccator and weighed (W_2) (“AOAC Quirino et al., 2022; Official Method 962.09Fiber (Crude) in Animal Feed and Pet Food: Ceramic Fiber Filter Method,” 2023). The crude fiber was calculated using equation 3.6:

$$\text{Crude Fibre (\%)} = \frac{W_1 - W_2}{W} \times 100 \quad (3.6)$$

Where:

W_1 =Weight of crucible +dried residue (g)

W_2 = Weight of crucible + ash (g)

W = Weight of original sample (g)

3.3.4 Determination of ash content

Fine powders of formulated fish feed were obtained using a pestle and mortar. A hot air oven was used at 105 °C for 3 hours to pre-dry the samples, and then

cooled in a desiccator before analysis. Clean, dry porcelain crucibles were ignited in a muffle furnace at 550 °C for 1 hour, cooled in a desiccator, and weighed (W_1). Approximately 2.0 g of each dried sample was accurately weighed into the crucible and recorded (W_2). The crucibles containing the samples were placed in a muffle furnace and incinerated at 550 °C for 5 hours until light grey or white ash was obtained (Quirino et al., 2022). The crucibles were carefully removed, cooled in a desiccator, and weighed (W_3). The heating–cooling–weighing cycle was repeated until a constant weight was achieved. The percentage of ash was calculated using equation 3.9:

$$\text{Ash Content (\%)} = \frac{W_3\text{-}W_1}{W_2\text{-}W_1} \times 100 \qquad (3.7)$$

Where:

W_1 = Weight of empty crucible (g), W_2 = Weight of crucible + sample before ashing (g), W_3 = Weight of crucible + sample after ashing (g)

3.3.5 Determination of moisture content

Representative samples were stored in airtight containers before analysis to prevent moisture absorption from the environment. Clean moisture dishes were dried in an oven at 105 ± 2 °C for 1 hour, then cooled in a desiccator and weighed (W_1). Approximately 2.0 g of each sample was placed in the dish and weighed (W_2) (AOAC 930.15 Moisture Content Determination in Foods, n.d.).The dishes containing the samples were dried in a hot air oven at 105 ± 2 °C for 3 hours. After drying, the dishes were transferred to a desiccator, allowed to cool to room temperature, and weighed (W_3). Drying, cooling, and weighing were repeated until a constant weight was obtained (“AOAC Official Method 930.15Loss on Drying (Moisture) for Feeds (at 135°C for 2 Hours): Dry Matter on Oven Drying for Feeds (at 135°C for 2 Hours),” 2023). The percentage of moisture was calculated using equation 3.10:

$$\text{(\%)Moisture Content} = \frac{W_2\text{-}W_3}{W_2\text{-}W_1} \times 100 \qquad (3.8)$$

Where:

W_1 = Weight of empty dish (g), W_2 = Weight of dish + sample before drying (g), W_3 = Weight of dish + sample after drying (g)

3.3.6 Determination of sodium chloride

5.0 g of finely ground sample was weighed and put into a 200 mL volumetric flask. 150 mL of deionized water was added. The mixture was shaken vigorously and was left to stand for 30 minutes, shaking at intervals. Topped up to the mark and shook vigorously before transferring the filter paper into a jam bottle. an aliquot of 25 mL was pipetted into a 250 mL conical flask. 20 mL of silver nitrate (0.1 N) was added and swirled. 5 mL ferric alum indicator and 2 mL nitrobenzene were added. The mixture was shaken well to coagulate the precipitate, and then was titrated with 0.1 N NH_4SCN to a reddish-brown endpoint. When the first perceptible color was obtained, the solution should be shaken vigorously, and the titration continued until a permanent color was obtained. A blank titration was carried out using 20 mL of silver nitrate solution and the same volumes of reagents and 25 mL of deionized water in place of the sample (Deucher et al., 2024) . The percentage of sodium chloride was calculated using equation 3.9:

$$\% \text{ NaCl} = \frac{\text{Blank titre-Sample titre} \times 0.5845 \times 8}{\text{weight of sample}} \quad (3.9)$$

3.3.7 Determination of calcium by the gravimetric method

1 g of finely ground sample was weighed into a silica crucible, and was ignited on heating mantles until no more carbon fumes came out. The crucible was transferred into the muffle furnace using metal tongs and ignited to carbon-free ash, but avoid fusing. the crucible was removed after 3 hours and was put in the desiccators to cool. The sample was weighed to get percentage ash. The crucible was placed under the fume hood. Drops of deionized water were added to moisten the ash, and 5 mL of concentrated HCl was added. The residue was transferred into the 100 mL volumetric flask and topped to the mark. The stopper was placed and the mixture was mixed thoroughly. 25 mL of clear liquid was placed into the beaker, and was diluted to the 150 mL mark. Two drops of methyl red indicator were added, then ammonium hydroxide dropwise to pH 5.6, as shown by a yellowish color. Hydrochloric acid was added drop-wise to a pink color showing a pH of 2.5 to 3. The mixture was

then brought to a boil, and slowly, with constant stirring, 10 mL of boiling saturated ammonium oxalate solution was added using a 10 mL-graduated pipette. Ammonium oxalate was added; the color changed to yellow; hydrochloric acid was added dropwise to a pink color. The solution was allowed to stand for over 5 hours to allow the precipitate to settle. The precipitate was filtered using a glass filter crucible. The precipitate was washed thoroughly using 500 mL of ammonium hydroxide. A glass filter was placed with the precipitate in the original beaker. Made up to the 150 mL mark with deionized water, and 5 mL of concentrated Sulphuric Acid was added. Then the mixture was heated to about 70 °C or above and was titrated with 0.1 N potassium permanganate until the first slightly pink color is obtained. A blank without 25 mL of the sample was made, but with everything the same (Syafrinal et al., 2025). The percentage of calcium was calculated using equation 3.10:

1 mL of K_2MnO_4

= 0.2004 g of Ca

$$\% \text{ Calcium} = \frac{\text{Titre -Blank} \times 0.2004}{\text{Sample weight} \times 0.25} \quad (3.10)$$

3.4 Determination of mycotoxins

The instrument used for the determination of mycotoxins consists of mycotoxin test kits (Manufactured by Romer Labs and uses Agravision software). The QR card, which contains information specific to the test kit's lot, was inserted into the reader (the slot is centrally located in the port system). The QR code information was stored by tapping the save icon. Each QR code only needs to be scanned once per lot (Li et al., 2021). 10 g of finely ground, formulated fish feed sample from potato peel was weighed, and one extraction buffer bag was added to a Whirl-Pak* filter bag. 50 mL of

deionized water was added, and the Whirl-Pak* filter bag was closed. The Whirl-Pak bag was vigorously shaken for 2 minutes. The Whirl-Pak* filter bag was opened, and the filter was placed on the same side as the sample. The sample was allowed to settle for 1 minute. 1000 µL dilution buffer was added using a blue pipette tip into a microcentrifuge tube. 100 µL of sample extract supernatant was transferred from the filter bag to the microcentrifuge tube (1:11 dilution). The extract from the side opposite the weighed sample was taken. The weighed sample was centrifuged for 30 seconds at 2000 g using a microcentrifuge. Then, the supernatant was collected for further testing (Vardali et al., 2023).

3.5 Determination of pellet durability index (P

D

I)

Two methods were used, which are the high velocity method (standard tumbling/air blast high-energy test) and the modified high velocity Method (reinforced impact / modified tumbling with metal impellers or nuts).

3.5.1 Pellet durability index (PDI) – high velocity method

PDI measures the resistance of pellets to breakage under high-speed mechanical agitation (tumbling or air blast stress). It simulates transport and pneumatic handling in feed mills (Yoder, 2016; Abbas et al., 2024). 500 g of pellet feed sample was collected. Fines were removed using a standard sieve. Samples were conditioned at room temperature (to avoid moisture variation). 100 g of intact pellets were weighed. The initial weight was recorded as (W_o). The pellets were placed in a high-speed PDI tester (tumbling box or air-blast chamber). Operated at: 55 rpm tumbling speed or high-velocity air jet (depending on instrument design). It was operated for 10 minutes. After tumbling, the sample was removed and sieved using a standard screen (usually 2–3 mm mesh). The intact pellets were separated from fines. The remaining intact pellets were weighed. The final weight was recorded as (W_1). The PDI was calculated using equation 3.11:

$$PDI = \frac{W_1}{W_0} \times 100 \qquad (3.11)$$

Where :

W_1 = Final weight recorded

W_0 = Initial weight recorded

PDI = Pellet Durability Index

3.5.2 Modified High Velocity Method (Fish Feed Adaptation)

This method increases mechanical stress using metal impellers/hex nuts, stronger tumbling forces, and longer agitation time. It was used especially for aquatic feeds requiring high water stability. A 100 g pellet sample was weighed, and the weight was recorded as W_o. The pellets were placed into a

metal tumbler box or Holmen-type chamber. 3–5 metal nuts or baffles (impact enhancers) were added. This increases collision intensity and mimics pneumatic transport damage. The metal tumbler box was then rotated at 50–320 rpm for 5–10 minutes. The sample was removed and sieved using standard mesh (2–3 mm). The intact pellets were weighed as W_1 (Abbas et al., 2024). The PDI was calculated using equation 3.12:

$$PDI = \frac{W_1}{W_0} \times 100 \quad (3.12)$$

Where :

W_0 = Initial recorded weight

W_1 = Final recorded weight

PDI = Pellet Durability Index

CHAPTER 4: RESULTS AND DISCUSSION

3.6 Percentage yield

The percentage yield was calculated using Equation 4.1:

$$\text{yield (\%)} = \frac{\text{weight of final extract}}{\text{weight of dry potato peel powder}} \quad (4.1)$$

Table 4.1: Percentage yield of potato peel phenolic extract

Sample	Initial weight of powder (g)	Weight of extract (g)	Percentage yield (%)
Trial 1	10.00	0.490	4.90
Trial 2	10.00	0.504	5.04
Trial 3	10.00	0.476	4.76
Average	10.00	0.490±0.014	4.90±0.14



Figure 4.1: Concentrated phenolic extract

The percentage yield of the final extract was 4.90±0.14 %, and the concentrated extract exhibited a yellowish-green color shown in Fig 4.1 above. The phenolic compounds were successfully extracted from potato peel using ethanol as a polar solvent. Particle size of the potato peel powder, extraction time, and the ratio of solvent to solid matter can affect the extraction yield. The percentage yield of the extract (4.90±0.14 %) is consistent with the one reported by (Xu et al., 2022b), who reported a 4 to 6 % yield using 70 % ethanol. For effective phenolic antioxidant extraction, ethanol was used to recover the compounds, and yields 4.90 ±0.14%. The percentage yields are shown in table

4.1 above.

3.7Total Phenolic Content

Fig 4.2 shows a greenish-black color was produced to show the presence of

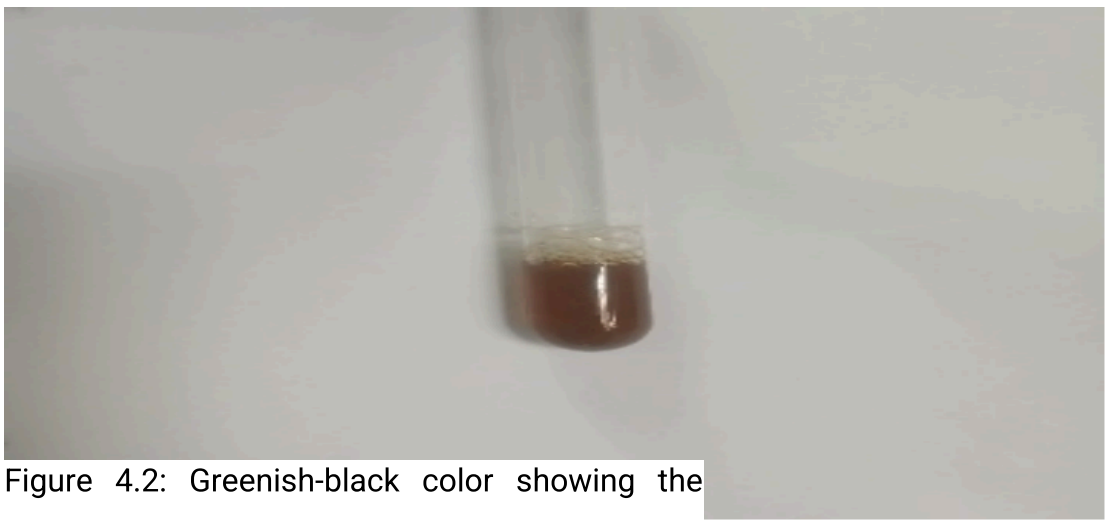


Figure 4.2: Greenish-black color showing the

phenolics after the addition of 1% ferric chloride reagent.

The TPC of the extract is expressed as gallic acid equivalent, which is 84.7±0.6 mg GAE/ 10 g (8.47±0.06 mg GAE/g), which, when compared to the TPC reported by (Brahmi et al., 2022). It is slightly lower due to the extraction method and the ethanol concentration (Brahmi et al., 2022). This was chosen to estimate the concentration of total phenolics in the extracts because the R^2 of 0.9992 indicates good linearity over the chosen range.

3.8 Hydrogen peroxide scavenging activity

Fig. 4.3 shows both the potato peel extract and ascorbic acid standard, exhibits increasing curves suggesting the activity of the antioxidant is based on concentration (Siddeeg et al., 2020). Potato peel phenolic extract exhibits a medium clearance activity of 28.4% on the lowest concentration (20 µg/mL) with a rapidly increasing trend and linearity, and a max capacity of 82.5% when reaching the highest concentration at 100 µg/mL. Potato peel extract showed a parallel curve to that of a pure ascorbic acid standard at a higher capacity near-saturated rate (98.2%). The TPC of potato peel

extract was 8.47 ± 0.06 mg GAE/g, which explains the very high hydrogen peroxide scavenging capacity at the limits (82.5%). The activity of the antioxidant is high if the IC50 values are lower. Potato peel extract showed a 49.82% IC50 value and was higher than that of pure ascorbic acid (24.16%),

Absorbance of potato peel extract (A_{sample})	0.716	0.579	0.413	0.287	0.175
Absorbance of ascorbic acid (A_{sample})	0.548	0.362	0.209	0.086	0.018
Absorbance of control ($A_{control}$)	1.000	1.000	1.000	1.000	1.000

which is commonly obtained in novel natural product investigations. The potato peel extract was able to achieve 50% inhibition at <50 µg/ml, proving to have a high activity, which corresponds to reports done on the use of other agricultural waste (Gulcin, 2020). Absorbances of sample and standard are shown in table 4.2 and scavenging activities are shown in table 4.3

Table 4.2: Absorbances of sample and standard

Table 4.3: Scavenging Activity

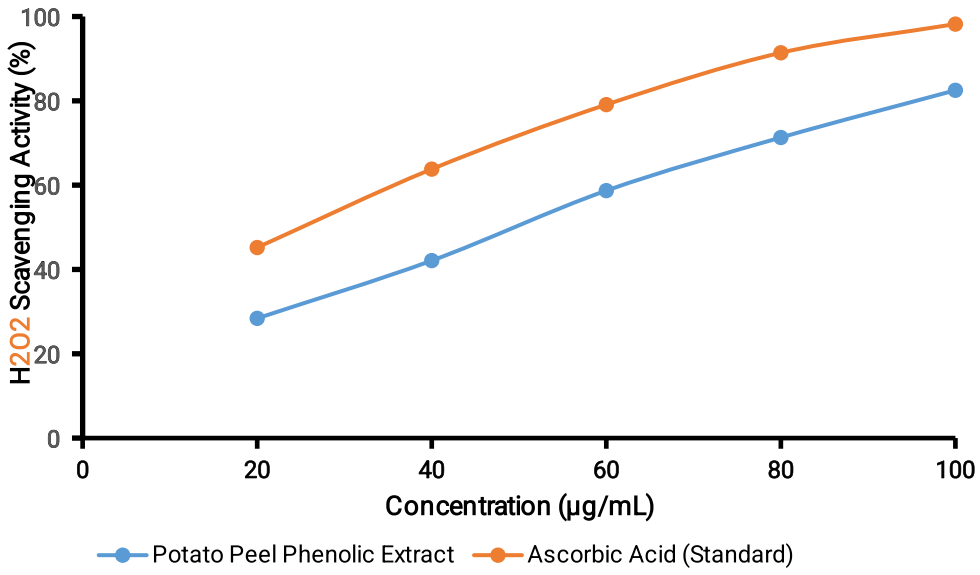


Figure 4.3: hydrogen peroxide

Tested Sample	20 µg/mL	40 µg/mL	60 µg/mL	80 µg/mL	100 µg/mL	Calculated IC_{50} (µg/mL)
Potato Peel Extract	28.4 % ± 1.2	42.1 ± 1.5	58.7 ± 1.9	71.3 ± 1.1	82.5 ± 2.1	49.82
Ascorbic Acid Standard	45.2 ± 0.8	63.8 ± 1.1	79.1 ± 1.4	91.4 ± 0.9	98.2 ± 0.5	24.16

3.9 Characteristics of raw potato peels, potat

potato peel extract, and formulated feed

3.9.1 Fourier Transform Infrared Spectroscopy Analysis (FTIR)

FTIR spectra were plotted for PPE, PPP, and FFF to view changes in chemical functional groups occurring at different stages of synthesis. The potato peel

extract (Figure 4.5) shows functional groups for carbohydrates (starch and cellulose), phenolics, and proteins. A broad and strong peak was found at about 3400 cm^{-1} corresponding to the –OH stretch in water, starch, or phenolics (Mushtaq et al., 2023). Another sharp, medium peak at about 1635 cm^{-1} corresponds to C=O or C=C stretch which is most likely due to amides present in proteins or conjugated carbonyls/alkenes present in phenolics (chlorogenic acid) (Eichhorn et al., 2024). Furthermore, another peak was found to be broad and deep at about 1100 cm^{-1} due to the C-O stretch, which represents the characteristic bonds present in the glycosidic links of polysaccharides (starch, cellulose, or pectin).

Potato peel powder (Figure 4.4) displays a broad, shallow peak at approximately 3300 cm^{-1}, due to -OH stretch, which is representative of cellulose, hemicellulose, and lignin. A sharp, needle-like peak at about 2360 cm^{-1} corresponds to the CO_2 interface, and a sharp, jagged peak was also observed at approximately 1650 cm^{-1}, corresponding to the C=O or C=C stretch in pectin, phenolics, or amides. A strong, sharp peak was also present at 1020 cm^{-1}, due to C-O stretch, indicating the presence of lignocellulose (Mushtaq et al., 2024).

The FTIR spectra for the FFF show a characteristic multicomplex matrix which typically consists of proteins, fats, and carbohydrates (Figure 4.6). This spectrum has a broad peak around 3280 cm^{-1} corresponding to the O-H overtone stretch, which is representative of the carbohydrates and proteins. Sharp, twin peaks are present at 2925 cm-1 and 2855 cm^{-1} corresponding to C -H stretching (CH_2, CH_3), and these are typically found in fats/lipids. A small, sharp peak is also observed at 1745 cm^{-1} corresponding to the C=O stretch in the ester of triglycerides (lipids) (Santos-Iparraguirre et al., 2026). A medium to strong peak at about 1640 cm^{-1}, representing C=O or the Amide I peak for proteins, and another amide II peak representing N-H bending in proteins can be seen at 1540 cm^{-1}. A strong, sharp peak at 1025 cm^{-1}, corresponding to the C-O stretch, indicated the presence of carbohydrates (starch or cellulose) (Jóźwiak et al., 2026).

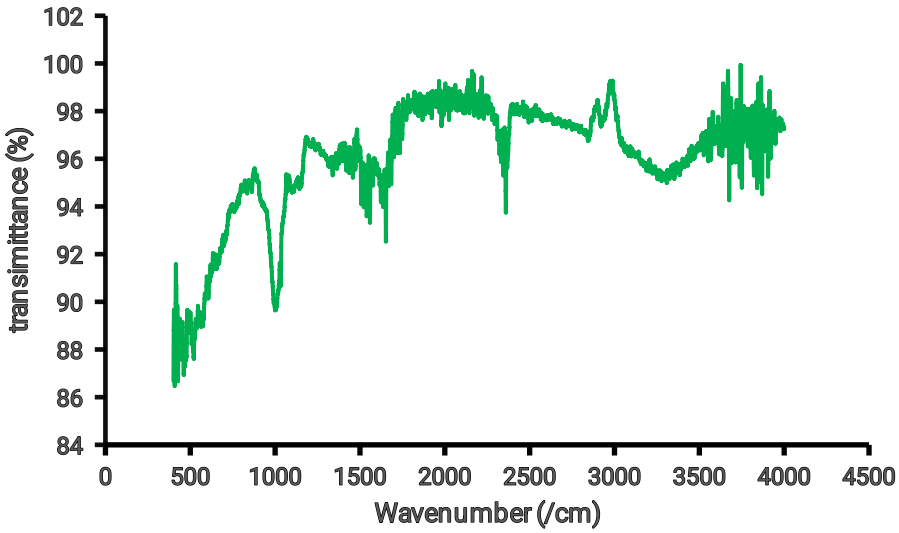


Figure 4.4: FTIR Spectrum of Potato Peel Powder

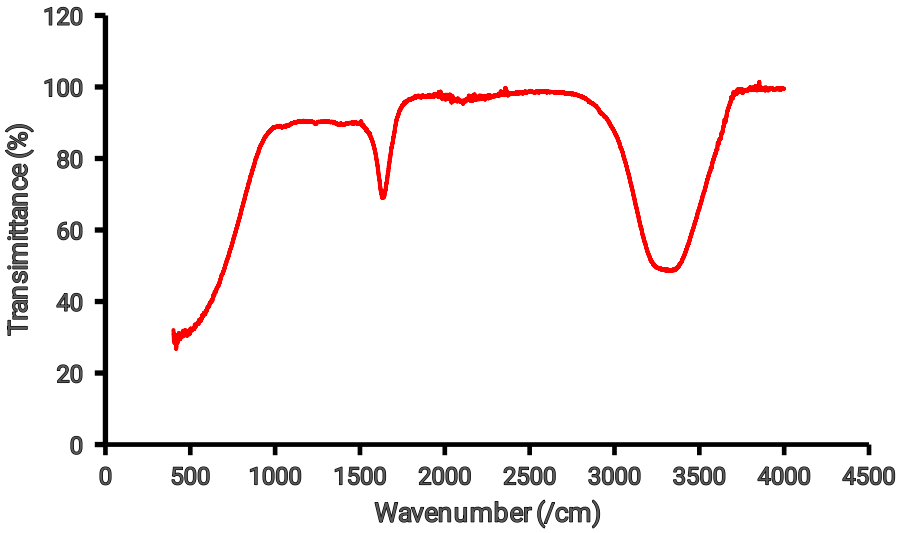


Figure 4.5: FTIR spectrum of potato peel extract (PPE)

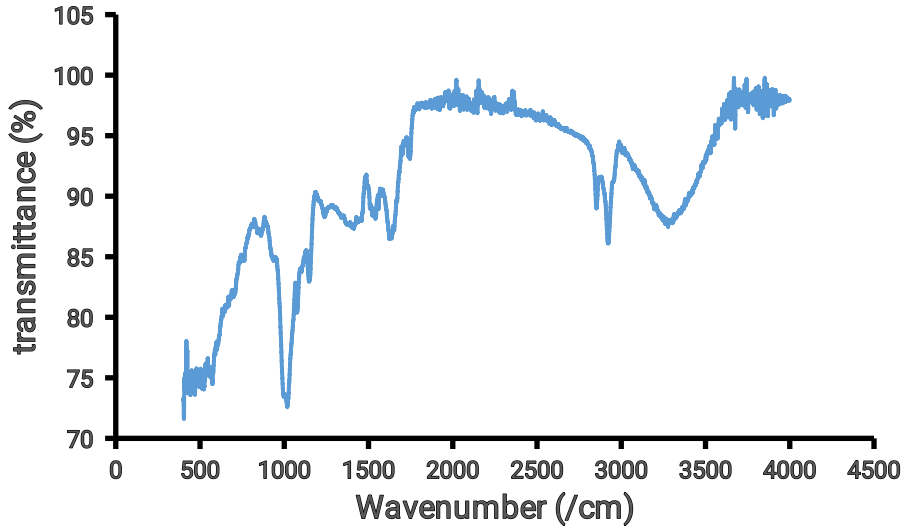


Figure 4.6: FTIR spectrum of potato peel fish feed

3.9.2 X-Ray Diffraction Analysis (XRD)

Differences in crystallinity were quantified by XRD of the potato peel powder and formulated feed. Figures 4.8, 4.7 and 4.9, showing the XRD patterns of the potato peel powder and formulated fish feed samples 1 and 2 revealed that many components used for preparing formulated feed were amorphous and poorly crystalline, as starch-rich and lignocellulosic components used for preparing feed materials for aquaculture are agro-wastes. Two broad peaks between approximately 15˚ and 25˚ (2Θ) indicate the semi-crystalline arrangement of starch structure, cellulose, hemicellulose, and amorphous organic matter (Daimary et al., 2022). Such broad peaks are typical for many studies on potato peel biomass and starch-rich feed components. (Sadeghi-Shapourabadi et al., 2023). Figure 4.8 shows a broad and strong hump between 18˚-22˚ (2Θ) for potato peel powder. This hump indicates the crystalline parts of native starch and cellulose, which are found in potato biomass-derived materials. It may appear due to the large percentage of non-crystalline polysaccharides such as hemicelluloses, lignin, and pectin, as well as partially disordered starch granules in the potato peel biomass, since the number of sharp diffraction peaks was not detected (Jeddou et al., 2016; Sadeghi-Shapourabadi et al., 2023).

Similar patterns have been previously reported for potato peel biomass. One broad hump (10˚-30˚ (2Θ)) and a few sharp peaks at approx. 30˚, 48˚, 57˚, 65˚, and 84˚(2Θ) for formulated feed sample 1 (Figure 4.7). The wide hump shows that the raw ingredients have decreased crystallinity due to gelatinization and formulation mixture preparation. It is widely accepted that the long-range order of starch will be lost during thermal processing and feed extrusion (Huang et al., 2022). The presence of some sharp peaks might represent inorganic components such as mineral salts or ashes that are added along with fishmeal and mineral premixes in the preparation of the fish feed. A similar decreasing trend in crystallinity due to thermal processing is normally observed in processed starchy products (Liu et al., 2022; van Rooyen et al., 2022). Has lower crystallinity and fewer sharp peaks compared with sample 1 in Figure 4.9. It had a few sharp crystalline peaks and showed a wide diffuse halo between 18˚-22˚(2Θ), suggesting that feed sample 2 was highly amorphous in structure.

A smaller number of sharp peaks indicated that the structural organization of the raw materials was greatly disrupted, and/or feed sample 2 contains higher amounts of amorphous materials, which would result in enhanced water absorption and therefore digestibility of fish feed and the increased nutrient use efficiency of fish. The structural character of the potato peel is preserved in the feed matrix since the formulated feed sample 2 resembled powdered potato peel in structure. However, formulated feed has much lower crystallinity compared to powdered potato peel, indicating crystalline parts from cellulose and starch were broken. Many previous studies demonstrated that the treatments of starchy materials (including heating, extrusion, and moisture conditioning) significantly reduced crystallinity due to disruption in the ordering of amylose and amylopectin (Qiu et al., 2024).

In most cases, fish feeds tend to be highly amorphous structures as these materials are easier to digest due to their higher availability to digestive

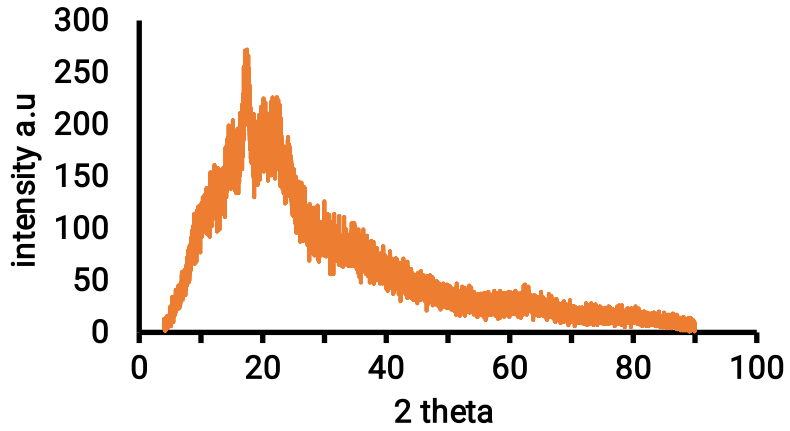


Figure 4.8: XRD Diffractogram for potato peel powder

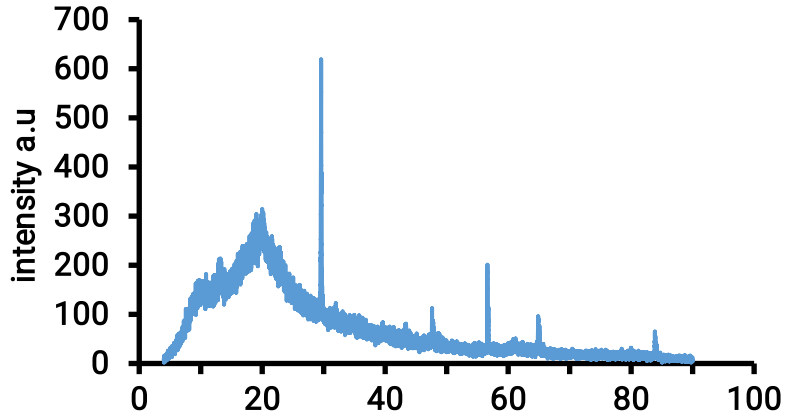


Figure 4.7: XRD Diffractogram for potato peel fish feed sample 1

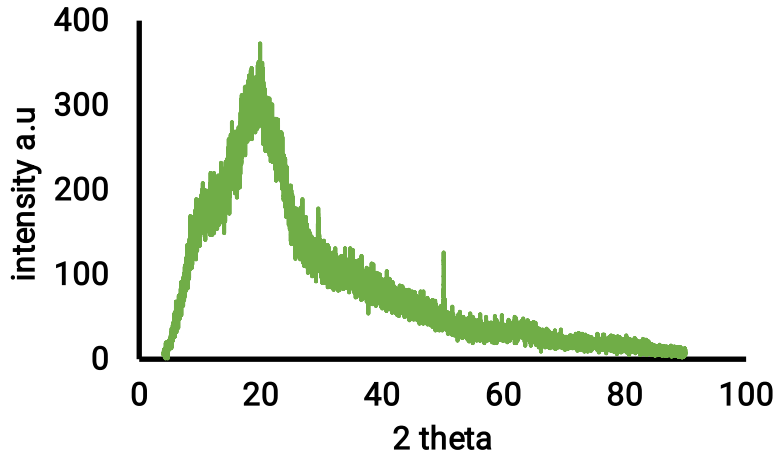


Figure 4.9: XRD Diffractogram for potato peel fish feed enzymes.

3.9.3 Thermogravimetric Analysis (TGA)

Figure 4.10 shows the TGA of potato peel powder, and it is characterized by a multiple-stage decomposition, which is typical for lignocellulosic biomass. First decrease in weight (approximately from 25 to 150 °C) refers to volatilization of volatile matter (which was water) from potato peel powder matrix; this refers to removal of physi-sorbed water. The potato peel powder matrix contains some moisture, and the first peak denotes the presence of water (Santos-Iparraguirre et al., 2026b). The high rate of weight reduction (between approx. 150 to 350 °C) corresponds to the decomposition of hemicellulose (~150 to 350 °C), starch (~300 °C), and cellulose (~290 to 360˚C) as well as other organic compounds; it indicates significant decomposition/volatilization of the carbohydrate fraction of biomass. Hemicellulose decomposed at an earlier temperature compared to cellulose, which has a steeper decomposition at a higher temperature, is expected (Quan et al., 2016). Gradual weight reduction above 350°C reflects lignin decomposition (being the most thermally stable) and formation of fixed carbon and ash.

Potato peel powder has good thermal stability below 200°C, so it can be used in feed processing applications at considerably below decomposition temperature. Figure 4.11 displays the thermal degradation of potato peel fish feed, also showing multiple stages of degradation. In this case, the first stage is the removal of physically bonded water and volatile matter entrapped into the matrix, which occurred at approximately between 25°C and 150°C, resulting in a relatively small weight reduction; it represents the early thermal degradation of the potato peel fish feed matrix and the dehydration processes referring to the evaporation of the free and weakly bonded water instead of the degradation of the structural organic fractions (Tripathi et al., 2025).

Principal decomposition of the feed occurred between approximately 200 and 380°C, with a steep decline of sample weight from about 87% to 40%. This decomposition stage was associated with the decomposition of starch, proteins, hemicellulose, cellulose, lipids, etc. These are present in potato peel and the other feed components. At higher than 380°C, weight reduction occurs at a slower rate, corresponding to decomposition of the most

thermally stable compounds to form carbonaceous residue; residue remaining at the higher temperature represents ash and fixed carbon content present in the fish feed.

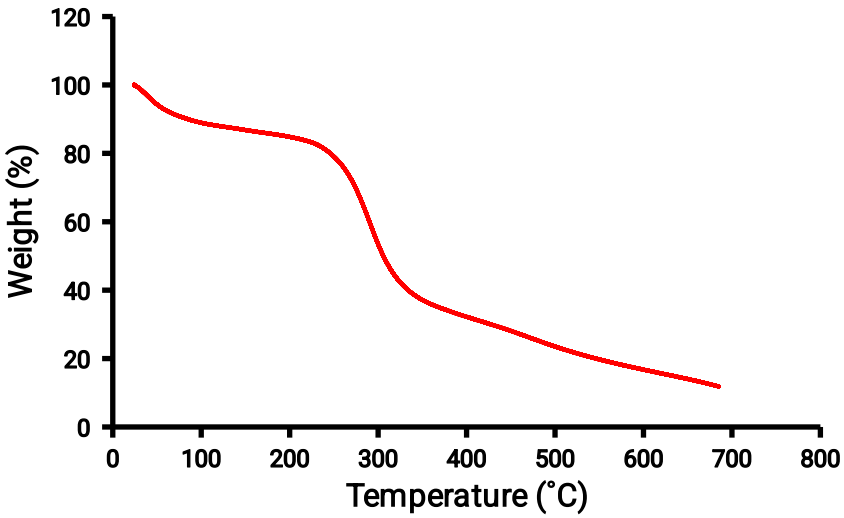


Figure 4.10: TGA Curve for potato peel powder

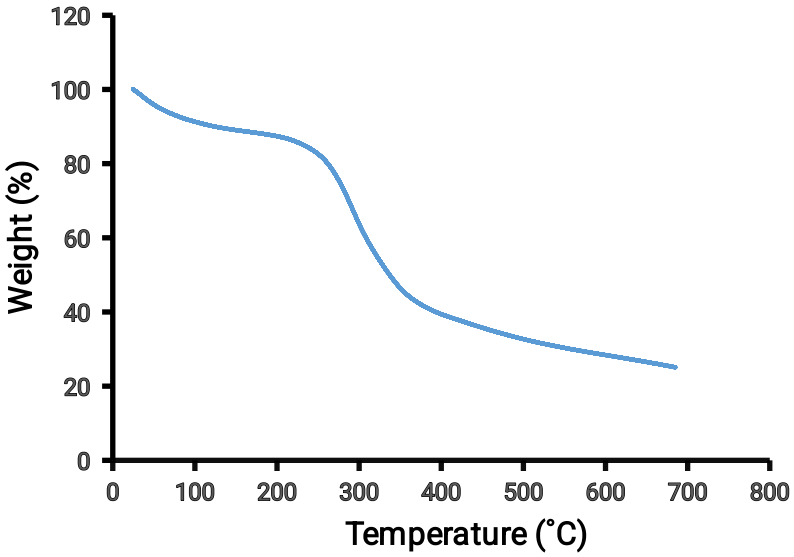


Figure 4.11: TGA Curve for potato peel

3.10 Proximate Analysis

The proximate chemical profiles of the experimental potato peel fish feed formulations (samples 1 to 8) demonstrate the significant structural variability across the test batches, reflecting the profound impact of formulation adjustments during waste-to-feed conversions.

3.10.1 Crude Protein

Crude protein remains the most critical and economically punitive component in commercial aquaculture feed production, particularly for freshwater species like Nile Tilapia (Oreochromis niloticus), which require 30 to 35% CP for the grower phase. The baseline deficit (samples 1 - 3): early formulations failed quality control testing due to profound protein deficiencies, with sample 1 yielding a low CP value of 14.49 %. This is entirely inadequate for commercial aquaculture, matching maintenance diets rather than production diets. The success threshold (samples 4 - 8): a significant breakthrough occurred from sample 4 onward, with crude protein increasing from 30.31% to a peak of 34.58% in sample 8. The National Foods Quality Assurance division officially passed these batches. These values align perfectly and, in some instances, exceed standard commercial grower benchmarks (~32.00% CP) available in the Zimbabwean market. This indicates that optimizing the inclusion logic of potato peel waste can support fish muscle deposition and

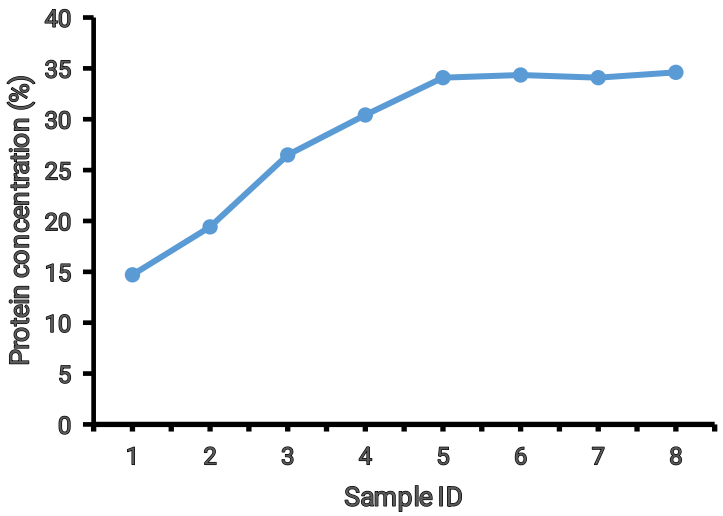


Figure 4.12: Protein Concentration

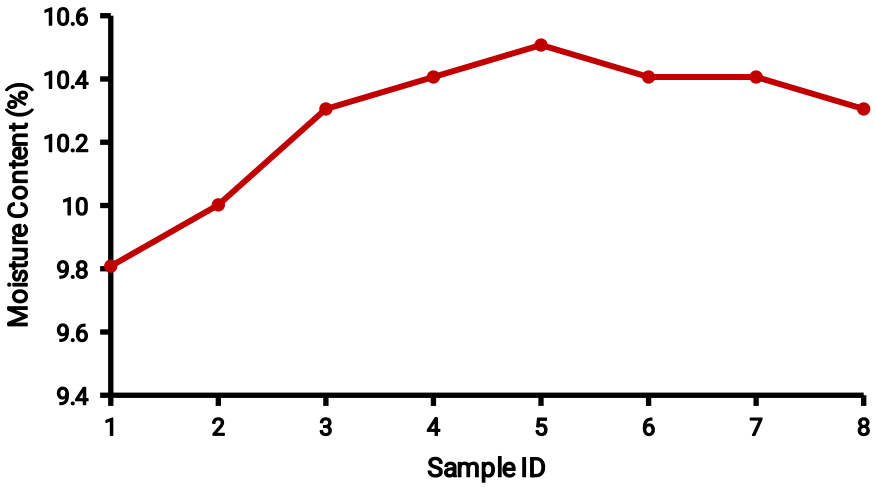
metabolic maintenance. Fig 4.12 below shows the protein concentrations across 8 samples.

3.10.2 Moisture

Moisture contents remained consistently tight across all eight samples (9.80

Figure 4.13: Moisture

% to 10.50%), safely below the critical 12.00 % industrial molding threshold. This guarantees excellent physical stability, starch gelatinization during pelleting, and shelf life against fungal colonization. Fig 4.13 below shows the moisture contents across 8 samples.



3.10.3 Micronutrient compositions (Calcium, Sodium, and Phosphorus)

The micro-mineral tracking showed calcium and phosphorus contents increased in a linear fashion with the trend of the quality of the feed. The failed feed formulation samples 1-3 showed 0.98% to 1.24% Ca and closely followed 0.77% to 0.87% P. The past feed formulation samples 4-8 showed optimized levels between 1.38% and 1.46% Ca and stable levels between 0.95% and 0.97% P. This gives an experimental Ca:P ratio of between about 1.45:1 and 1.5:1 in the successfully high-quality feeds. This ratio is easily well within the normal physiological range necessary to avoid malnutrition pathology (such as skeletal deformities and structural dwarfism) within freshwater species. The sodium level within feed formulations was stable between 0.19% and 0.22%, showing that none of the additional ingredients or minerals added with the potato peel introduced potentially fatal hypersaline conditions, and stable osmoregulation was maintained for aquaculture conditions. Fig 4.14 below shows the micronutrient concentrations.

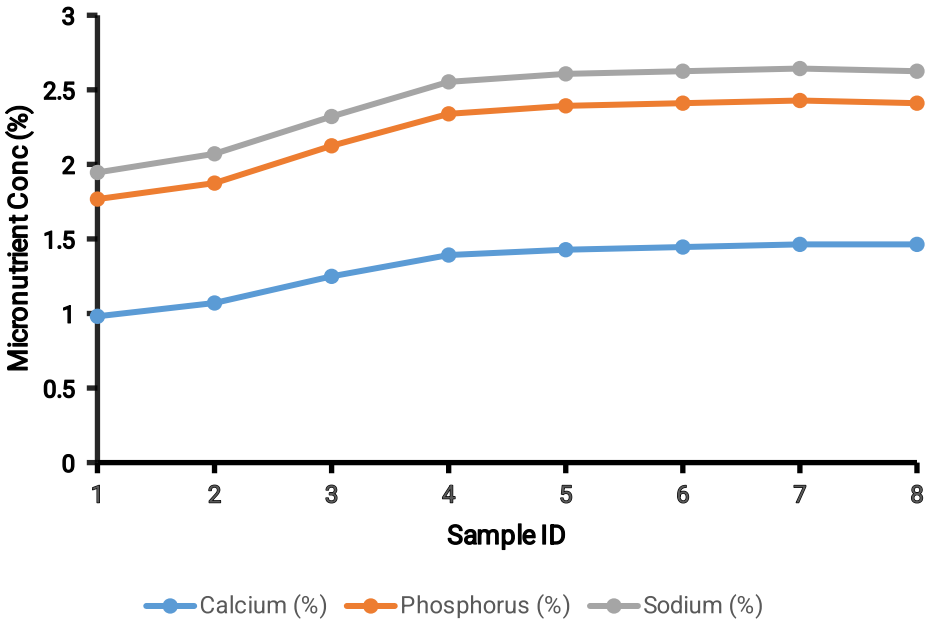


Figure 4.14: Micronutrient Concentration

3.11 Mycotoxins Profile (Aflatoxin, DON, ZON, Fum

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Aflatoxin registered at 2.6 – 2.8 ppb (parts per billion), which is well below the strict limit of 20 ppb, according to (Oliveira & Vasconcelos, 2020), which implies that the potato peels were fresh and stored under clean conditions before processing. DON (Deoxynivalenol/ Vomitoxin) registered at 0 ppm, eliminating any risk of feed refusal or intestinal damage, which was also supported by (Hooft & Bureau, 2021). ZON (Zearalenone) is present at minimal levels of 1.6 – 1.8 ppm. This falls safely within acceptable thresholds, presenting no risk of estrogenic disruption in the fish, and Fumonisin is registered at 0 ppm.

3.12 Pellet durability index

The samples recorded fines levels of 4.3–5.0%, indicating acceptable pellet integrity and low pellet breakdown. (Karim et al., 2024). Low fines are generally associated with good pellet durability and effective binding properties, suggesting that the starch component of potato peels contributed to pellet cohesion and resistance to crumbling during handling and transport.

3.13 Comparison of Nutritional Compositions of P

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Table 4.4: Comparing Potato peel fish feed to feed in the market

Table 4.4 above shows the proximate composition results indicate that the potato peel fish feed compares favorably with the two commercial feeds,

	Potato Peel Fish Feed	Profeeds Aquafeeds	TILA FEEDS	STANDARD	MY FORMULATION TARGET
Crude Protein (%)	35.0	32.0	32.0	30.0-35.0	32.0
Crude Fat (%)	5.3	6.0	6.0	4.0-7.0	5.0
Crude Fibre (%)	5.9	6.5	3.0	4.0-6.5	6.0
Ash (%)	6.2	6.5	8.0	8.0-12.0	6.5
Moisture (%)	11.4	12.0	10.8	10.0-12.0	11.0

Profeeds Aquafeeds and TILA Feeds, while meeting the targeted nutritional requirements. The crude protein content of the potato peel feed (35.0%) was higher than both Profeeds and TILA Feeds (32.0%) and was at the upper limit of the recommended range (30.0–35.0%), suggesting its suitability for supporting fish growth. The crude fat content (5.3%) was slightly lower than the commercial feeds (6.0%) but remained within the recommended range of 4.0–7.0%, providing adequate dietary energy. Crude fibre (5.9%) was comparable to Profeeds (6.5%) and higher than TILA Feeds (3.0%), indicating an acceptable fibre level for feed stability and digestion. The ash content (6.2%) was slightly lower than both commercial feeds and below the standard range of 8.0–12.0%, suggesting a lower mineral content that may require further optimization. Moisture content (11.4%) was similar to the commercial feeds and within the recommended range, indicating good storage stability. Overall, the potato peel fish feed demonstrated a nutritional profile comparable to commercial aquafeeds and achieved most of the formulation targets, highlighting its potential as a cost-effective and sustainable alternative feed ingredient.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study accomplished its aims in extracting phenolics from potato peels and then incorporating these into a formulated aquaculture feed. Potato peel powder is an attractive agro-industrial waste product that has functional, nutritional, and antioxidant capabilities that would aid in the sustainability of aquaculture systems. Phenolic compounds from the potato peels can be effectively extracted using ethanol and produce a significant yield of extract and high content of total phenolics. Hydrogen peroxide scavenging activity confirms that the activity of potato peel phenolics increases with concentration, thereby effectively removing the free radicals.

Structural analysis of potato peel powder and the formulated fish feed using FTIR showed -OH, C=C, C=O, N-H, C-H functional groups corresponding to the presence of phenolics, pectin, proteins, lignin, and hemicellulose. XRD showed sharp crystalline peaks and showed a wide diffuse halo between 18˚-22˚(2Θ), suggesting that feed sample 2 was highly amorphous in structure , and TGA confirms Principal decomposition of the feed occurred between approximately 200 and 380°C, with a steep decline of sample weight from about 87% to 40%. This decomposition stage was associated with the decomposition of starch, proteins, hemicellulose, cellulose, lipids, etc. Proximate analysis also showed nutritional composition (35 % crude protein, crude fat, 6 % crude fibre, ash, 11.5 % moisture) appropriate for use as a feed for fish. Substituting selected traditional ingredients with potato peel powder and phenolics will be cost-effective and provide a feed with added functional values.

In essence, potato peel is a cheap and readily available source of raw material that could be readily used for the formulation of aquaculture feeds. The use of phenolics derived from potato peel leads to cleaner waste management and

an efficient utilization of raw materials while helping to build a sustainable aquaculture system that adheres to the circular bio-economy. However, to find its potential use, further feeding experiments at a larger scale are essential to estimate its biological feeding performance, feed utilization, fish health, and economics under commercial farming conditions.

5.2 Recommendations

Further studies need to be carried out under optimized conditions of extracting phenolic antioxidants from potato peels (solvent concentration, time, temperature, and particle size) for maximum yield of extraction and antioxidant activity, and compare performance against other methods of extraction, such as ultrasonic-assisted extraction, microwave-assisted extraction, and enzyme-assisted extraction. Regarding the feeding trials, comprehensive trials need to be conducted in several fish species with varied levels of incorporation of potato peel powder and phenolic extracts into feeds, and factors like growth performance, feed conversion ratio, immune response, mortality, and flesh quality need to be evaluated. Long-term studies should also be conducted on the effects of the incorporation of potato peels in fish physiology and health to determine inclusion levels that pose no risk to the fish. The effects of these additions on feed quality also need to be investigated with additional characterization studies on phenolic compounds and the stability of antioxidants over storage. Tests on pellet water stability and pellet performance based on shelf life should be performed. The cost-benefit and economic feasibility of using potato peel extracts in fish feed production in Zimbabwe should also be examined.

REFERENCES

Abbas, B. A., Jasim, A. A., & Bander, L. K. (2024). Comparing Different Laboratory Methods for Measuring the Feed Pellet Durability. *Kufa Journal for Agricultural Sciences*, *16*(3), 50–60. https://doi.org/10.36077/KJAS/2024/V16I3.11401.

Abd El-Naby, A. S., El Asely, A. M., Amin, A. A., Samir, F., El-Ashram, A., & Dawood, M. A. O. (2020). Miswak (Salvadora persica) modulated the growth performance, antioxidative response, and histopathological damage induced by zinc toxicity in Nile tilapia (Oreochromis niloticus). *Environmental Science and Pollution Research*, *27*(25), 31918–31932. https://doi.org/10.1007/s11356-020-09429-1.

Abdel-Tawwab, M., Abo Selema, T. A. M., Khalil, R. H., El-Sabbagh, N., Eldessouki, E. A. A. Fawzy, R. M., & Abd El-Naby, A. S. (2022). The growth performance, antioxidant and immune responses, and disease resistance of Litopenaeus vannamei fed on diets supplemented with Indian ginseng (Withania somnifera). *Fish & Shellfish Immunology*, *128*, 19–27. https://doi.org/10.1016/J.FSI.2022.07.061.

Adedeji, A. E., Olalusi, A. P., Olayanju, T. M. A., & Erinle, O. C. (2020). Effect of Drying Parameters on the Physical Properties of Extruded Fish Feed. *IOP Conference Series: Earth and Environmental Science*, *445*(1), 012011. https://doi.org/10.1088/1755-1315/445/1/012011.

Ajani, E. K., Orisasona, O., Omitoyin, B. O., & Osho, E. F. (2016). Total replacement of fishmeal by Soybean Meal with or without methionine fortification in the diets of Nile tilapia, Oreochromis niloticus. *Journal of Fisheries and Aquatic Science*, *11*(3), 238–243. https://doi.org/10.3923/JFAS.2016.238.243.

Akyol, H., Riciputi, Y., Capanoglu, E., Caboni, M. F., & Verardo, V. (2024). *Molecular Sciences Phenolic Compounds in the Potato and Its Byproducts: An Overview*. https://doi.org/10.3390/ijms17060835.

Akyol, H., Riciputi, Y., Capanoglu, E., Caboni, M. F., & Verardo, V. (2016). Phenolic Compounds in the Potato and Its Byproducts: An Overview. *International Journal of Molecular Sciences 2016, Vol. 17, Page 835*, *17*(6), 835. https://doi.org/10.3390/IJMS17060835.

AOAC 930.15 Moisture Content Determination in Foods. (n.d.). Retrieved May 4, 2026, from https://www.testinglab.com/aoac-93015-moisture-content-determination-in-foods?utm_source=chatgpt.com.

AOAC Official Method 930.15Loss on Drying (Moisture) for Feeds (at 135°C for 2 Hours): Dry Matter on Oven Drying for Feeds (at 135°C for 2 Hours). (2023). *Official Methods of Analysis of AOAC INTERNATIONAL*. https://doi.org/10.1093/9780197610145.003.1384.

AOAC Official Method 962.09Fiber (Crude) in Animal Feed and Pet Food: Ceramic Fiber Filter Method. (2023). *Official Methods of Analysis of AOAC INTERNATIONAL*. https://doi.org/10.1093/9780197610145.003.1416.

Apostică, A. G., Ichim, T., Radu, V. M., & Bulgariu, L. (n.d.). *SIMPLE AND RAPID SPECTROPHOTOMETRIC METHOD FOR PHENOL DETERMINATION IN AQUEOUS MEDIA*.

At Apak, R., Mustafa, †, Zyü Rek, O.¨ , Gü Ç Lü , K., & Ç Apanoğ Lu, E. (2016). *Antioxidant Activity/Capacity Measurement. 1. Classification, Physicochemical Principles, Mechanisms, and Electron Transfer (ET)-Based Assays*. https://doi.org/10.1021/acs.jafc.5b04739.

Athipornchai, A., & Klangmanee, K. (2021). A rapid determination of the effective antioxidant agents using their Fe(III) complexes. *Arabian Journal of Chemistry*, *14*(3).

https://doi.org/10.1016/j.arabjc.2021.102986.

Awogbemi, O., & Kallon, D. V. Von. (2022). *Biofuel Generation from Potato Peel Waste : Current State and Prospects*. 1–17.

Bălăşoiu, R. M., Biţă, A., Stănciulescu, E. C., Rău, G., Bejenaru, C., Bejenaru, E., & Pisoschi, C. G. (2023). UHPLC/MS ASSESSMENT OF POLYPHENOLIC ACIDS AND RADICAL SCAVENGING ACTIVITY OF SALVIA SPECIES FROM THE SOUTH-WEST OF ROMANIA FLORA. *FARMACIA*, *71*, 4. https://doi.org/10.31925/farmacia.2023.4.5.

Bellumori, M., Innocenti, M., Michelozzi, M., Cerretani, L., & Mulinacci, N. (2017). Coloured-fleshed potatoes after boiling: Promising sources of known antioxidant compounds. *Journal of Food Composition and Analysis*, *59*, 1–7. https://doi.org/10.1016/J.JFCA.2017.02.004.

Benkeblia, N. (2020). Potato Glycoalkaloids: occurrence, biological activities and extraction for biovalorisation – a review. *International Journal of Food Science & Technology*, *55*(6), 2305–2313. https://doi.org/10.1111/IJFS.14330.

Brahmi, F., Mateos-Aparicio, I., Garcia-Alonso, A., Abaci, N., Saoudi, S., Smail-Benazzouz, L., Guemghar-Haddadi, H., Madani, K., & Boulekbache-Makhlouf, L. (2022). Optimization of Conventional Extraction Parameters for Recovering Phenolic Compounds from Potato (Solanum tuberosum L.) Peels and Their Application as an Antioxidant in Yogurt Formulation. *Antioxidants 2022, Vol. 11, Page 1401*, *11*(7), 1401. https://doi.org/10.3390/ANTIOX11071401.

Calín-Sánchez, Á., Lipan, L., Cano-Lamadrid, M., Kharaghani, A., Masztalerz, K., Carbonell-Barrachina, Á. A., & Figiel, A. (n.d.). *Comparison of Traditional and Novel Drying Techniques and Its Effect on Quality of Fruits, Vegetables and Aromatic Herbs*. https://doi.org/10.3390/foods9091261.

Cebulak, T., Krochmal-Marczak, B., Stryjecka, M., Krzysztofik, B., Sawicka, B., Danilčenko, H., & Jarienė, E. (2022). Phenolic Acid Content and Antioxidant Properties of Edible Potato (Solanum tuberosum L.) with Various Tuber Flesh Colours. *Foods 2023, Vol. 12, Page 100*, *12*(1), 100. https://doi.org/10.3390/FOODS12010100.

Chen, J., Wang, L., Wang, H., Zhang, G., & Wang, W. (2021). 基于伴随方程法的鱼饲料热特性参数反演. *农业工程学报, 2021, Vol. 37, Issue 19, Pages: 316-322*, *37*(19), 316–322. https://doi.org/10.11975/J.ISSN.1002-6819.2021.19.037.

Coklar, H., Akbulut, M., Kilinc, S., Yildirim, A., & Alhassan, I. (2018). Effect of Freeze, Oven and Microwave Pretreated Oven Drying on Color, Browning Index, Phenolic Compounds and Antioxidant Activity of Hawthorn (Crataegus orientalis) Fruit. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, *46*(2), 449–456. https://doi.org/10.15835/NBHA46211027.

Coşkun, N., Sarıtaş, S., Jaouhari, Y., Bordiga, M., & Karav, S. (2024). The Impact of Freeze Drying on Bioactivity and Physical Properties of Food Products. *Applied Sciences 2024, Vol. 14, Page 9183*, *14*(20), 9183. https://doi.org/10.3390/APP14209183.

Deucher, N. C., Silva de Souza, R., & Borges, E. M. (2024). Teaching Precipitation Titration Methods: a Statistical Comparison of Mohr, Fajans, and Volhard Techniques. *Journal of Chemical Education*, *102*(1), 364–371. https://doi.org/10.1021/ACS.JCHEMED.4C01037.

Espinoza-García, D. A., Torres-Martínez, B. del M., Vargas-Sánchez, R. D., Torrescano-Urrutia, G. R., & Sánchez-Escalante, A. (2023). Valorization of Potato Peel Waste as Natural Additive for Use in Meat Products. *Resources 2023, Vol. 12, Page 148*, *12*(12), 148. https://doi.org/10.3390/RESOURCES12120148.

Farooq, M. A., & Yu, J. (2024). Recent Advances in Physical Processing Techniques to Enhance the Resistant Starch Content in Foods: A Review. *Foods 2024, Vol. 13, Page 2770*, *13*(17), 2770. https://doi.org/10.3390/FOODS13172770.

FLORESCU, C. A. G., STANCIULESCU, E. C., BERBECARU-IOVAN, A., BALASOIU, R. M., & PISOSCHI, C. G. (2024). In vitro Assessment of Free Radical Scavenging Effect and Thermal Protein Denaturation Inhibition of Bee Venom for an Anti-Inflammatory Use. *Current Health Sciences Journal*, *50*(1), 81. https://doi.org/10.12865/CHSJ.50.01.11.

Gasco, L., Gai, F., Maricchiolo, G., Genovese, L., Ragonese, S., Bottari, T., & Caruso, G. (2018). *Fishmeal Alternative Protein Sources for Aquaculture Feeds*. 1–28. https://doi.org/10.1007/978-3-319-77941-6_1.

Grillo, G., Tabasso, S., Capaldi, G., Radosevic, K., Radojčić-Redovniković, I., Gunjević, V., Calcio Gaudino, E., & Cravotto, G. (2023). Food-Waste Valorisation: Synergistic Effects of Enabling Technologies and Eutectic Solvents on the Recovery of Bioactives from Violet Potato Peels. *Foods 2023, Vol. 12, Page 2214*, *12*(11), 2214. https://doi.org/10.3390/FOODS12112214.

Gupta, M., Dey, A., Majumder, S., Ghosh, S., & Barui, A. (2022). Evaluation of Antioxidant Activity Using by H2O2, DPPH, ABTS Methods and Phytochemical Tests, TPC & TFC of Commonly Used Medicinal Plants of West Bengal. *International Journal of Pharmaceutical Sciences Review and Research*, *72*(1). https://doi.org/10.47583/ijpsrr.2022.v72i01.018.

Hu, X., Ma, W., Zhang, D., Tian, Z., Yang, Y., Huang, Y., & Hong, Y. (2025). Application of Natural Antioxidants as Feed Additives in Aquaculture: A Review. *Biology 2025, Vol. 14, Page 87*, *14*(1), 87. https://doi.org/10.3390/BIOLOGY14010087.

Huang, X., Liu, H., Ma, Y., Mai, S., & Li, C. (2022). Effects of Extrusion on Starch Molecular Degradation, Order–Disorder Structural Transition and Digestibility—A Review. *Foods 2022, Vol. 11, Page 2538*, *11*(16), 2538. https://doi.org/10.3390/FOODS11162538.

Ijaz, N., Bashir, S., Ikram, A., Zafar, A., Ul Ain, H. B., Ambreen, S., Ahmad, M., Almalki, R. S., Khalid, M. Z., Khalid, W., & Madilo, F. K. (2024). Valorization of potato peel: a sustainable eco-friendly approach. In *CYTA - Journal of Food* (Vol. 22, Number 1). Taylor and Francis Ltd. https://doi.org/10.1080/19476337.2024.2306951.

Ismail, H. F., Akhir, F. N. M., Othman, N., & Hara, H. (2024). Optimization of Extraction Solvents on the Antioxidant Properties of Coconut Waste. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, *117*(1), 109–117. https://doi.org/10.37934/arfmts.117.1.109117.

Jantra, J., Teepoo, S., & Suchera Thananimit, ·. (123 C.E.). Smartphone-based imaging colorimetric assay for monitoring the quality of curcumin in turmeric powder. *Analytical Sciences*, *40*, 1311–1321. https://doi.org/10.1007/s44211-024-00562-2.

Jeddou, K. Ben, Chaari, F., Maktouf, S., Nouri-Ellouz, O., Helbert, C. B., & Ghorbel, R. E. (2016). Structural, functional, and antioxidant properties of water-soluble polysaccharides from potatoes peels. *Food Chemistry*, *205*, 97–105. https://doi.org/10.1016/J.FOODCHEM.2016.02.108.

Jimenez-Champi, D., Romero-Orejon, F. L., Moran-Reyes, A., Muñoz, A. M., & Ramos-Escudero, F. (2023). Bioactive compounds in potato peels, extraction methods, and their applications in the food industry: a review. In *CYTA - Journal of Food* (Vol. 21, Number 1, pp. 418–432). Taylor and Francis Ltd. https://doi.org/10.1080/19476337.2023.2213746.

Joly, N., Souidi, K., Depraetere, D., Wils, D., & Martin, P. (2020). Potato By-Products as a Source of Natural Chlorogenic Acids and Phenolic Compounds: Extraction, Characterization, and Antioxidant Capacity. *Molecules 2021, Vol. 26, Page 177*, *26*(1), 177. https://doi.org/10.3390/MOLECULES26010177.

Karim, A., Naila, B., Khwaja, S., Hussain, S. I., & Ghafar, M. (2024). Evaluation of different Starch Binders on physical quality of fish feed pellets. *Brazilian Journal of Biology*, *84*. https://doi.org/10.1590/1519-6984.256242.

Knez, E., Kadac-Czapska, K., & Grembecka, M. (2025). Evaluation of Spectrophotometric Methods for Assessing Antioxidant Potential in Plant Food Samples—A Critical Approach. *Applied Sciences 2025, Vol. 15, Page 5925*, *15*(11), 5925. https://doi.org/10.3390/APP15115925.

Kozin, A. V., Abramova, L. S., Guseva, E. S., Derunets, I. V., Kozin, A. V., Abramova, L. S., Guseva, E. S., & Derunets, I. V. (2022). Establishment of metrological parameters of the method for measuring the protein mass fraction in fish food products by the Kjeldahl method. *Food Systems*, *4*(4), 239–245. https://doi.org/10.21323/2618-9771-2021-4-4-239-245.

Kumar, S., Yadav, A., Yadav, M., & Parkash Yadav, J. (2017). Effect of climate change on phytochemical diversity, total phenolic content and in vitro antioxidant activity of Aloe vera (L.) Burm.f. *BMC Res Notes*, *10*, 60. https://doi.org/10.1186/s13104-017-2385-3.

Kumari, D., Madhujith, T., & Chandrasekara, A. (2017). Comparison of phenolic content and antioxidant activities of millet varieties grown in different locations in Sri Lanka. *Food Science and Nutrition*, *5*(3), 474–485. https://doi.org/10.1002/FSN3.415.

Lalas, S. I., Núñez-Pérez, J., Burbano-García, J. L., Espín-Valladares, R., Lara-Fiallos, M. V, Carlos DelaVega-Quintero, J., Cevallos-Vallejos, M., & Pais-Chanfrau, J.-M. (2026). Cascade Valorisation of Lemon-Processing Residues (Part I): Current Trends in Green Extraction Technologies and High-Value Bioactive Recovery. *Foods 2026, Vol. 15, Page 491*, *15*(3), 491. https://doi.org/10.3390/FOODS15030491.

Lee, S. H., Oh, S. H., Hwang, I. G., Kim, H. Y., Woo, K. S., Woo, S. H., Kim, H. S., Lee, J., & Jeong, H. S. (2016). Antioxidant Contents and Antioxidant Activities of White and Colored Potatoes (Solanum tuberosum L.). *Preventive Nutrition and Food Science*, *21*(2), 110. https://doi.org/10.3746/PNF.2016.21.2.110.

Li, R., Wen, Y., Wang, F., & He, P. (2021). Recent advances in immunoassays and biosensors for mycotoxins detection in feedstuffs and foods. *Journal of Animal Science and Biotechnology 2021 12:1*, *12*(1), 108-. https://doi.org/10.1186/S40104-021-00629-4.

Liu, X., Huang, S., Chao, C., Yu, J., Copeland, L., & Wang, S. (2022). Changes of starch during thermal processing of foods: Current status and future directions. *Trends in Food Science & Technology*, *119*, 320–337. https://doi.org/10.1016/J.TIFS.2021.12.011.

López-Cruz, R., Sandoval-Contreras, T., & Iñiguez-Moreno, M. (2023). Plant Pigments: Classification, Extraction, and Challenge of Their Application in the Food Industry. In *Food and Bioprocess Technology* (Vol. 16, Number 12, pp. 2725–2741). Springer. https://doi.org/10.1007/s11947-023-03075-4.

Lucas, B. N., Dalla Nora, F. M., Boeira, C. P., Verruck, S., & Da Rosa, C. S. (2022). Determination of total phenolic compounds in plant extracts via Folin-Ciocalteu's method adapted to the usage of digital images. *Food Science and Technology (Brazil)*, *42*. https://doi.org/10.1590/fst.35122

Mæhre, H. K., Dalheim, L., Edvinsen, G. K., Elvevoll, E. O., & Jensen, I. J. (2018). Protein Determination—Method Matters. *Foods 2018, Vol. 7, Page 5*, *7*(1), 5. https://doi.org/10.3390/FOODS7010005.

Makori, S. I., Mu, T. H., & Sun, H. N. (2021). Profiling of Polyphenols, Flavonoids and Anthocyanins in Potato Peel and Flesh from Four Potato Varieties. *Potato Research 2021 65:1*, *65*(1), 193–208. https://doi.org/10.1007/S11540-021-09516-X.

Makori, S. I., Mu, T. H., & Sun, H. N. (2022). Profiling of Polyphenols, Flavonoids and Anthocyanins in Potato Peel and Flesh from Four Potato Varieties. *Potato Research*, *65*(1), 193–208. https://doi.org/10.1007/s11540-021-09516-x.

Maksimenko, A., Belyi, L., Podvolotskaya, A., Son, O., & Tekutyeva, L. (2024). Exploring Sustainable Aquafeed Alternatives with a Specific Focus on the Ensilaging Technology of Fish Waste. In *Fermentation* (Vol. 10, Number 5). Multidisciplinary Digital Publishing Institute (MDPI). https://doi.org/10.3390/fermentation10050258.

Martinez-Fernandez, J. S., Seker, A., Davaritouchaee, M., Gu, · Xiangyu, & Chen, S. (2021). *Recovering Valuable Bioactive Compounds from Potato Peels with Sequential Hydrothermal Extraction*. *12*, 1465–1481. https://doi.org/10.1007/s12649-020-01063-9.

Michiu, D., Socaciu, M. I., Fogarasi, M., Jimborean, A. M., Ranga, F., Mureşan, V., & Semeniuc, C. A. (2022). Implementation of an Analytical Method for Spectrophotometric Evaluation of Total Phenolic Content in Essential Oils. *Molecules 2022, Vol. 27, Page 1345*, *27*(4), 1345. https://doi.org/10.3390/MOLECULES27041345.

Mostafa, F. A., Wehaidy, H. R., El-Hennawi, H. M., Mahmoud, S. A., Sharaf, S., & Saleh, S. A. A. (2024).

Statistical Optimization of α-Amylase Production from Novel Local Isolated Bacillus spp. NRC1 and Its Textile Applications. *Catalysis Letters 2024 154:7*, *154*(7), 3264–3275. https://doi.org/10.1007/S10562-023-04545-2.

Mushtaq, Q., Ishtiaq, U., Joly, N., Martin, P., & Qazi, J. I. (2024). Investigation and characterization of changes in potato peels by thermochemical acidic pre-treatment for extraction of various compounds. *Scientific Reports 2024 14:1*, *14*(1), 12655-. https://doi.org/10.1038/s41598-024-63364-6.

Mushtaq, Q., Joly, N., Martin, P., & Qazi, J. I. (2023). Optimization of Alkali Treatment for Production of Fermentable Sugars and Phenolic Compounds from Potato Peel Waste Using Topographical Characterization and FTIR Spectroscopy. *Molecules*, *28*(21). https://doi.org/10.3390/molecules28217250.

Nayak, M., Saha, A., Pradhan, A., Samanta, M., Mohanty, T. K., & Giri, S. S. (2018). Influence of dietary lipid levels on growth, nutrient utilization, tissue fatty acid composition and desaturase gene expression in silver barb (Puntius gonionotous) fingerlings. *Comparative Biochemistry and Physiology Part B: Biochemistry and Molecular Biology*, *226*, 18–25. https://doi.org/10.1016/J.CBPB.2018.08.005.

Nenciu, F., Voicea, I., Stefan, V., Nae, G., Matache, M., Milian, G., & Arsenoaia, V. N. (2022). EXPERIMENTAL RESEARCH ON A FEED PELLETIZING EQUIPMENT DESIGNED FOR SMALL AND MEDIUM-SIZED FISH FARMS. *INMATEH - Agricultural Engineering*, *67*(2), 374–383. https://doi.org/10.35633/INMATEH-67-38.

Nisca, A., Ștefănescu, R., Moldovan, C., Mocan, A., Mare, A. D., Ciurea, C. N., Man, A., Muntean, D. L., & Tanase, C. (2022). Optimization of Microwave Assisted Extraction Conditions to Improve Phenolic Content and In Vitro Antioxidant and Anti-Microbial Activity in Quercus cerris Bark Extracts. *Plants 2022, Vol. 11, Page 240*, *11*(3), 240. https://doi.org/10.3390/PLANTS11030240

Official Methods of Analysis℠ Program - AOAC INTERNATIONAL. (n.d.). Retrieved May 4, 2026, from https://www.aoac.org/scientific-solutions/standards-and-official-methods/?utm_source=chatgpt.com.

Okolie, P. C., Chukwujike, I. C., Chukwuneke, J. L., & Dara, J. E. (2019). Design and production of a fish feed pelletizing machine. *Heliyon*, *5*(6). https://doi.org/10.1016/J.HELIYON.2019.E02001.

ONUOHA, P. C. (2018). BINDING POTENTIAL, WATER STABILITY AND PHYSICAL PROPERTIES OF FOUR LOCALLY AVAILABLE BINDERS ON FORMULATED FISH FEED. *Nigerian Journal of Fisheries*, *15*(1), 1388–1392. https://fisonjournal.org.ng/index.php/njf/article/view/173.

Pacifico, D., Lo Scalzo, R., Calzone, A., Nicoletti, F., Parisi, B., Cassol, H., Bianchi, G., & Lanzanova, C. (2024). Potato Peel as a Natural Source of Biocompounds for Cereal Fungal Control. *ACS Food Science & Technology*, *4*(8), 1864–1874. https://doi.org/10.1021/ACSFOODSCITECH.4C00189.

Qiu, C., Hu, H., Chen, B., Lin, Q., Ji, H., & Jin, Z. (2024). Research Progress on the Physicochemical Properties of Starch-Based Foods by Extrusion Processing. *Foods 2024, Vol. 13, Page 3677*, *13*(22), 3677. https://doi.org/10.3390/FOODS13223677.

Quirino, D. F., Palma, M. N. N., Franco, M. O., & Detmann, E. (2022). Variations in Methods for Quantification of Crude Ash in Animal Feeds. *Journal of AOAC International*, *106*(1), 6–13. https://doi.org/10.1093/JAOACINT/QSAC100.

Raposo, F., Borja, R., & Gutiérrez-González, J. A. (2024). A comprehensive and critical review of the unstandardized Folin-Ciocalteu assay to determine the total content of polyphenols: The conundrum of the experimental factors and method validation. *Talanta*, *272*, 125771. https://doi.org/10.1016/J.TALANTA.2024.125771.

Riciputi, Y., Diaz-de-Cerio, E., Akyol, H., Capanoglu, E., Cerretani, L., Caboni, M. F., & Verardo, V. (2018). Establishment of ultrasound-assisted extraction of phenolic compounds from industrial potato by-products using response surface methodology. *Food Chemistry*, *269*, 258–263. https://doi.org/10.1016/J.FOODCHEM.2018.06.154.

Rigneault, H., Kumar, N. G., Cossart, R., Septier, D., Brévalle-Waslilewki, G., Kudlinski, A., & Kaszas, A. (2025). Antioxidant Activity of Hydroethanolic Extracts of Asteracantha longifolia and Moringa oleifera Using DPPH, Nitric Oxide, Hydrogen Peroxide and Frap Model. *Asian Journal of Biology*, *21*(7), 120–129. https://doi.org/10.34894/VQ1DJA.

Rizvi, N. B., Fatima, A., Busquets, R., Khan, M. R., Ashraf, S., Khan, M. S., & Oz, F. (2023). Effect of the Media in the Folin-Ciocalteu Assay for the Analysis of the Total Phenolic Content of Olive Products. *Food Analytical Methods 2023 16:11*, *16*(11), 1627–1634. https://doi.org/10.1007/S12161-023-02527-Z.

Rodríguez-Martínez, B., Gullón, B., & Yáñez, R. (2021). Identification and Recovery of Valuable Bioactive Compounds from Potato Peels: A Comprehensive Review. *Antioxidants 2021, Vol. 10, Page 1630*, *10*(10), 1630. https://doi.org/10.3390/ANTIOX10101630.

Sadeer, N. B., Montesano, D., Albrizio, S., Zengin, G., & Mahomoodally, M. F. (2020). The Versatility of Antioxidant Assays in Food Science and Safety—Chemistry, Applications, Strengths, and Limitations. *Antioxidants 2020, Vol. 9, Page 709*, *9*(8), 709. https://doi.org/10.3390/ANTIOX9080709.

Sadeghi-Shapourabadi, M., Elkoun, S., & Robert, M. (2023). Microwave-Assisted Chemical Purification and Ultrasonication for Extraction of Nano-Fibrillated Cellulose from Potato Peel Waste. *Macromol 2023, Vol. 3, Pages 766-781*, *3*(4), 766–781. https://doi.org/10.3390/MACROMOL3040044.

Saleem, T., Naveed, A., Bibi, A., & Saleem, S. (2025). Fish Feed Development by Potato Peel Incorporation in Fish Diet. *Indus Journal of Bioscience Research*, *3*(12), 227–236. https://doi.org/10.70749/ijbr.v3i12.2806.

Samotyja, U. (2019). Potato Peel as a Sustainable Resource of Natural Antioxidants for the Food Industry. *Potato Research*, *62*(4), 435–451. https://doi.org/10.1007/s11540-019-9419-2.

Sampaio, S. L., Petropoulos, S. A., Alexopoulos, A., Heleno, S. A., Santos-Buelga, C., Barros, L., & Ferreira, I. C. F. R. (2020). Potato peels as sources of functional compounds for the food industry: A review. *Trends in Food Science & Technology*, *103*, 118–129. https://doi.org/10.1016/J.TIFS.2020.07.015.

Schieber, A. (2017). Side Streams of Plant Food Processing As a Source of Valuable Compounds: Selected Examples. In *Annual Review of Food Science and Technology* (Vol. 8, pp. 97–112). Annual Reviews Inc. https://doi.org/10.1146/annurev-food-030216-030135.

Silva-Beltrán, N. P., Chaidez-Quiroz, C., López-Cuevas, O., Ruiz-Cruz, S., López-Mata, M. A., Del-Toro-sánchez, C. L., Marquez-Rios, E., & Ornelas-Paz, J. D. J. (2017). Phenolic compounds of potato peel extracts: Their antioxidant activity and protection against human enteric viruses. *Journal of Microbiology and Biotechnology*, *27*(2), 234–241. https://doi.org/10.4014/jmb.1606.06007.

Singh, B., Singh, J., Singh, J. P., Kaur, A., & Singh, N. (2020). Phenolic compounds in potato (Solanum tuberosum L.) peel and their health-promoting activities. In *International Journal of Food Science and Technology* (Vol. 55, Number 6, pp. 2273–2281). Blackwell Publishing Ltd. https://doi.org/10.1111/ijfs.14361.

Singh, S. K., Patel, J. R., & Dangi, A. (2019). Physicochemical, Qualitative and Quantitative Determination of Secondary Metabolites and Antioxidant Potential of Kalanchoe Pinnata (Lam.) Pers. Leaf Extracts. *Journal of Drug Delivery & Therapeutics*, *9*(1), 220. https://doi.org/10.22270/JDDT.V9I1.2225.

Sridhar, K., & Charles, A. L. (2019). In vitro antioxidant activity of Kyoho grape extracts in DPPH and ABTS assays: Estimation methods for EC50 using advanced statistical programs. *Food Chemistry*, *275*, 41–49. https://doi.org/10.1016/J.FOODCHEM.2018.09.040.

Suslavich, B., LaDouceur, R., Mamudu, A., & Young, C. (2024). Synthesis and characterization of hydroxamic acid N,3-dihydroxy-2-naphthamide and its copper (II) complex per keto/enol forms and rare earth flotation. *Miner Miner Mater 2024;3:1.*, *3*(1), N/A-N/A. https://doi.org/10.20517/MMM.2023.25.

Syafrinal, S., Hafnimardiyanti, Samah, S. D., Riani, P., Futeri, R., & Nurmaliza. (2025). Verification of The Method for Determining Calcium Content in Animal Feed. *Chempublish Journal*, *9*(2), 313–329. https://doi.org/10.22437/CHP.V9I2.48076.

Thi, N. D. D., Nguyen, M. T., Bui Thi, B. H., Mai, Q. Q., Nguyen, P. V., & Nguyen, Q. V. (2024). Optimizing Polyphenolic Extraction from Wild Guava Leaves: A Response Surface Methodology Approach to Antioxidant and α-Glucosidase Inhibitory Activities. *Natural Product Communications*, *19*(12). https://doi.org/10.1177/1934578X241308480.

Tripathi, D., Kumari, M., Chauhan, A. K., Kumar, D., & Dhondale, M. R. (2025). A study on red potato peel (Solanum tuberosum L. cv. Red Holland): characterization, composition and formulation of tablet using different drying techniques. *Journal of Food Science and Technology*, *62*(1), 122–133. https://doi.org/10.1007/s13197-024-06015-y.

van Rooyen, J., Simsek, S., Oyeyinka, S. A., & Manley, M. (2022). Holistic View of Starch Chemistry, Structure and Functionality in Dry Heat-Treated Whole Wheat Kernels and Flour. *Foods 2022, Vol. 11, Page 207*, *11*(2), 207. https://doi.org/10.3390/FOODS11020207.

Vardali, S., Papadouli, C., Rigos, G., Nengas, I., Panagiotaki, P., & Golomazou, E. (2023). Recent Advances in Mycotoxin Determination in Fish Feed Ingredients. *Molecules 2023, Vol. 28, Page 2519*, *28*(6), 2519. https://doi.org/10.3390/MOLECULES28062519.

Vescovo, D., Manetti, C., Ruggieri, R., Spizzirri, U. G., Aiello, F., Martuscelli, M., & Restuccia, D. (2025). The Valorization of Potato Peels as a Functional Ingredient in the Food Industry: A Comprehensive Review. In *Foods* (Vol. 14, Number 8). Multidisciplinary Digital Publishing Institute (MDPI). https://doi.org/10.3390/foods14081333.

Xu, Q., Wang, S., Milliron, H., & Han, Q. (2022). The Efficacy of Phenolic Compound Extraction from Potato Peel Waste. *Processes 2022, Vol. 10, Page 2326*, *10*(11), 2326. https://doi.org/10.3390/PR10112326.

Yoder, A. D. (2016). 0983 Effects of Dakota gold and high fat commodity DDGS in a complete diet on pellet quality. *Journal of Animal Science*, *94*(suppl_5), 472–472. https://doi.org/10.2527/JAM2016-0983.

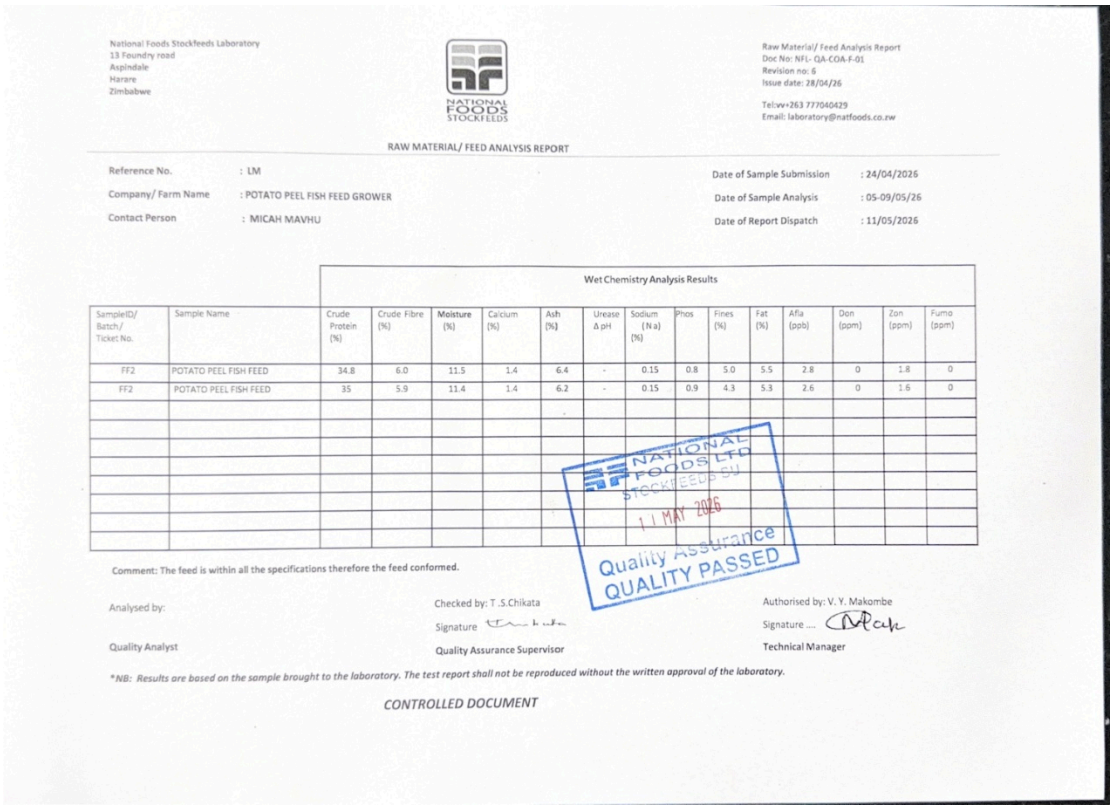
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Yuksel, F., & Durmaz, A. (2022). *Evaluation of By-Products of Potato Peel as Food Additive us e Current Nutrition & Food Science at e riv di er so na Fo r p te d or tri bu ot b e up lo a de d to an yo n e or on an re e riv an l p up a Fo r p d bu b he*. 15–21. https://doi.org/10.2174/1573401317666210702110412.

Zahra Siddiqui, S., Saleem, H., Athar Abbasi, M., & Ajaib, M. (2017). Lonicera quinquelocularis: A rich source of antioxidant for protection against chronic diseases. *Pak. J. Pharm. Sci*, *30*(2), 347–353.

Zhang, Y., Zhou, W. E., Yan, J. Q., Liu, M., Zhou, Y., Shen, X., Ma, Y. L., Feng, X. S., Yang, J., & Li, G. H. (2018). A Review of the Extraction and Determination Methods of Thirteen Essential Vitamins to the Human Body: An Update from 2010. *Molecules 2018, Vol. 23, Page 1484*, *23*(6), 1484. https://doi.org/10.3390/MOLECULES23061484.

APPENDIX



National Foods Stockfeeds Laboratory
13 Foundry road
Aspindale
Harare
Zimbabwe

NATIONAL FOODS STOCKFEEDS

Raw Material/ Feed Analysis Report
Doc No: NFL- QA-COA-F-01
Revision no: 6
Issue date: 28/04/26

Tel:vv+263 777040429
Email: laboratory@natfoods.co.zw

RAW MATERIAL/ FEED ANALYSIS REPORT

Reference No. : LM
Company/ Farm Name : POTATO PEEL FISH FEED GROWER
Contact Person : MICAH MAVHU

Date of Sample Submission : 24/04/2026
Date of Sample Analysis : 05-09/05/26
Date of Report Dispatch : 11/05/2026

		Wet Chemistry Analysis Results													
SampleID/ Batch./ Ticket No.	Sample Name	Crude Protein (%)	Crude Fibre (%)	Moisture (%)	Calcium (%)	Ash (%)	Urease Δ pH	Sodium (Na) (%)	Phos	Fines (%)	Fat (%)	Afla (ppb)	Don (ppm)	Zon (ppm)	Fumo (ppm)
FF2	POTATO PEEL FISH FEED	34.8	6.0	11.5	1.4	6.4	-	0.15	0.8	5.0	5.5	2.8	0	1.8	0
FF2	POTATO PEEL FISH FEED	35	5.9	11.4	1.4	6.2	-	0.15	0.9	4.3	5.3	2.6	0	1.6	0

NATIONAL FOODS LTD STOCKFEEDS BU
11 MAY 2026
Quality Assurance
QUALITY PASSED

Comment: The feed is within all the specifications therefore the feed conformed.

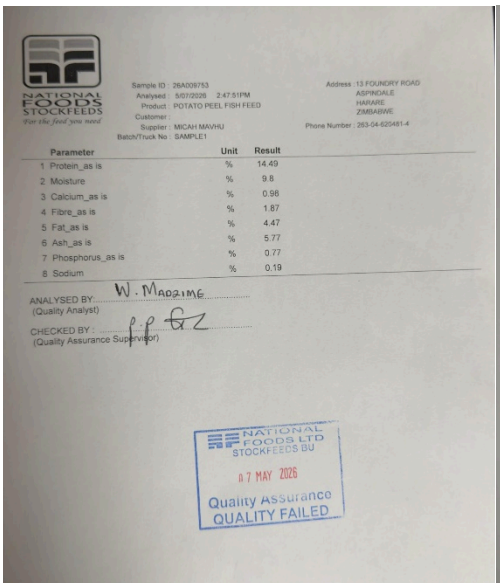
Analysed by:
Quality Analyst

Checked by: T .S.Chikata
Signature
Quality Assurance Supervisor

Authorised by: V. Y. Makombe
Signature ....
Technical Manager

NB: Results are based on the sample brought to the laboratory. The test report shall not be reproduced without the written approval of the laboratory.

CONTROLLED DOCUMENT



NATIONAL FOODS STOCKFEEDS
'For the feed you need'

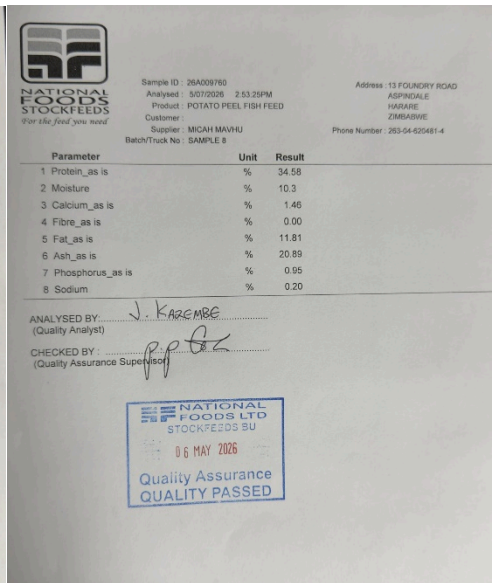
Sample ID : 26A009753
Analysed : 5/07/2026 2:47:51PM
Product : POTATO PEEL FISH FEED
Customer :
Supplier : MICAH MAVHU
Batch/Truck No : SAMPLE1

Address :13 FOUNDRY ROAD
ASPINDALE
HARARE
ZIMBABWE
Phone Number : 263-04-620481-4

Parameter	Unit	Result
1 Protein_as is	%	14.49
2 Moisture	%	9.8
3 Calcium_as is	%	0.98
4 Fibre_as is	%	1.87
5 Fat_as is	%	4.47
6 Ash_as is	%	5.77
7 Phosphorus_as is	%	0.77
8 Sodium	%	0.19

ANALYSED BY: W. MADZIME
(Quality Analyst)
CHECKED BY :
(Quality Assurance Supervisor)

NATIONAL FOODS LTD STOCKFEEDS BU
07 MAY 2026
Quality Assurance
QUALITY FAILED



NATIONAL FOODS STOCKFEEDS
'For the feed you need'

Sample ID : 26A009760
Analysed : 5/07/2026 2:53:25PM
Product : POTATO PEEL FISH FEED
Customer :
Supplier : MICAH MAVHU
Batch/Truck No : SAMPLE 8

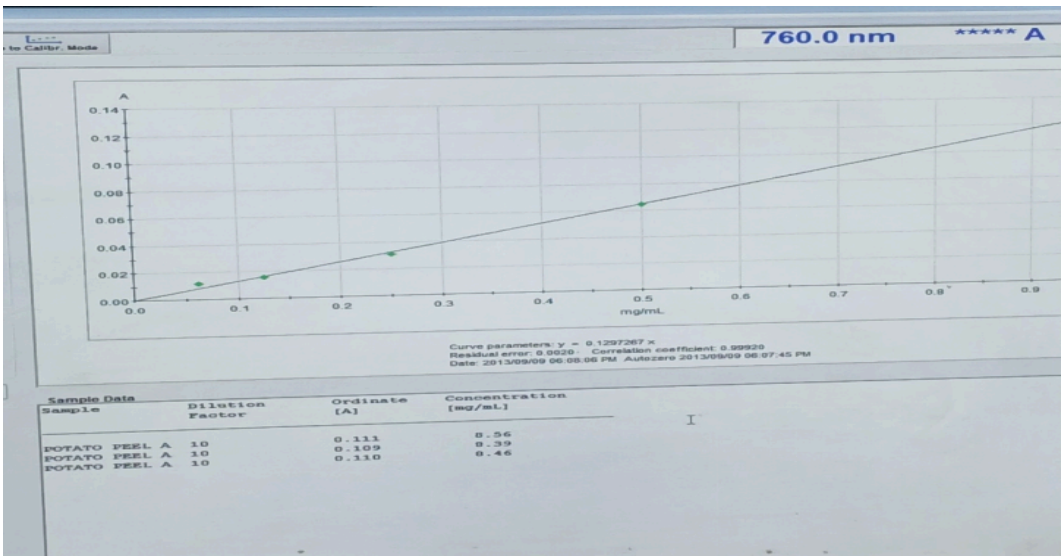
Address :13 FOUNDRY ROAD
ASPINDALE
HARARE
ZIMBABWE
Phone Number : 263-04-620481-4

Parameter	Unit	Result
1 Protein_as is	%	34.58
2 Moisture	%	10.3
3 Calcium_as is	%	1.46
4 Fibre_as is	%	0.00
5 Fat_as is	%	11.81
6 Ash_as is	%	20.89
7 Phosphorus_as is	%	0.95
8 Sodium	%	0.20

ANALYSED BY: J. KAZEMBE
(Quality Analyst)
CHECKED BY :
(Quality Assurance Supervisor)

NATIONAL FOODS LTD STOCKFEEDS BU
06 MAY 2026
Quality Assurance
QUALITY PASSED


VESSEL


760.0 nm
***** A
A
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
mg/mL
Curve parameters: y = 0.1297267 x
Residual error: 0.0020 Correlation coefficient: 0.99920
Date: 2013/09/09 06:08:06 PM Autozero 2013/09/09 06:07:45 PM
Sample Data
Sample
Dilution Factor
Ordinate [A]
Concentration [mg/mL]
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POTATO PEEL A 10 0.109 0.39
POTATO PEEL A 10 0.110 0.46