

**DEVELOPMENT OF FEED GRADES FROM SWEET POTATO (*Ipomoea batatas*
L. Lam) LEAF PROTEIN CONCENTRATE AND PEELED TUBER**

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BENIN CITY,
NIGERIA.**

MAY, 2024.

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**A PROJECT SUBMITTED TO THE DEPARTMENT OF ANIMAL
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NIGERIA.**

MAY, 2024.

CERTIFICATION

This is to certify that this Project work was carried out by Kizito Chinaemezu OKORIE (AGR1800138) under the guidance of the Project Supervisors approved by the Department of Animal Science, Faculty of Agriculture, University of Benin, Benin City, Nigeria.

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DEDICATION

This work is dedicated to God Almighty, the Giver of all understanding and the Source of all wisdom. Also, to my family, and to all those who, through their love, trust, finance and moral support, I was able to go all the way through the course of this study.

ACKNOWLEDGEMENT

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ABSTRACT

This study was carried out to develop feed grades (25% 50%, 75%), from Sweet potato (*Ipomoea batatas* L. LAM) leaf protein concentrate and peeled tubers. The leaf protein concentrate was extracted using heat coagulation method, while the peeled potato tubers were thoroughly dried before grinding. Both products were reconstituted with a known volume of water and then left to dry before being subjected to analysis for some chemical composition. The proximate and mineral compositions were significantly different across the treatments ($p < 0.05$). The dry matter of the 100SPLPC was 90.25%, which was not significantly different from 89.86% for 100PT ($p > 0.05$). The crude protein of 100SPLPC was revealed to be significantly higher (39.84%) than that of 100PT ($p < 0.05$). The crude fibre of 100SPLPC was significantly lower (1.11%) than 100PT (7.93%). Ether extract content was higher in 100SPLPC (9.93%) than in 100PT (5.30%). 100PT also revealed a higher ash content (8.37%) than 100SPLPC (5.83%) at $p < 0.05$. The NFE content of 100SPLPC was significantly lower (43.29%) than that of 100PT at $p < 0.05$. The minerals, Ca, K, P, Na, Mg, Zn, Mn and Fe were found to be significantly higher in the peeled tuber than the leaf protein concentrate ($p < 0.05$), hence justifying the inclusion of the peeled tuber to the diet. Sweet potato leaf protein concentrate and peeled tuber have the potential to be used as a feed resource in the livestock industry.

CHAPTER ONE

1.0 INTRODUCTION

The ever-increasing global population and the subsequent rise in demand for food and feed have necessitated the exploration of alternative protein sources to complement traditional sources. In this context, the utilization of underutilized and often discarded plant materials, such as sweet potato leaves and peels, has garnered significant attention (Atu *et al.*, 2022). Sweet potato (*Ipomoea batatas L.*) is a widely cultivated crop known for its energy-rich tubers and nutritious leaves, which are frequently discarded or underutilized (Antia *et al.*, 2006).

The development of feed grades using sweet potato leaf protein concentrate (SPLPC) and peeled tubers presents a promising solution to address the growing demand for sustainable and cost-effective feed sources. Leaves of the sweet potato plant are rich in essential amino acids, vitamins, and minerals, making them an attractive source of protein for animal feed (Omole *et al.*, 2018). Additionally, the peeled tubers, which are typically considered waste, contain valuable carbohydrates and other nutrients that can contribute to the overall nutritional profile of the feed (Tewe *et al.*, 2003).

One of the primary challenges in utilizing sweet potato leaves and peels as feed ingredients is their low digestibility and the presence of anti-nutritional factors, such as tannins and oxalates (Antia *et al.*, 2006; Okoh *et al.*, 2016). Therefore, the development

of feed grades using SPLPC and peeled tubers requires effective processing techniques to enhance their nutritional value and reduce the impact of undesirable compounds.

1.1 JUSTIFICATION

The utilization of SPLPC and peeled tubers in feed formulations not only addresses the issue of food waste but also contributes to the development of sustainable and environmentally friendly feed production practices (Atu *et al.*, 2022). Furthermore, the incorporation of these alternative protein and energy sources can potentially reduce the reliance on traditional feed ingredients, such as soybean meal and corn, which are subject to price fluctuations and supply constraints (Tewe *et al.*, 2003).

This study aims to develop feed grades using SPLPC and peeled tubers through various processing techniques and evaluate their nutritional and chemical composition, and potential for incorporation into animal diets. By exploring the synergistic effects of SPLPC and peeled tubers, this research endeavors to create a balanced and cost-effective feed formulation that can contribute to sustainable animal production and improved food security.

1.2 Objectives of the Study

The objective of this study was to develop feed grades using Sweet potato (*Ipomoea batatas L.*) leaf protein concentrate and peeled tuber.

The specific objectives were to:

1. develop feed grade containing sweet potato leaf protein concentrate and peeled sweet potato tuber in varying but known ratios.
2. analyze the chemical composition of each of these feed grades.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 ORIGIN AND DISTRIBUTION OF SWEET POTATO PLANT

Sweet potato (*Ipomoea batatas*) is a dicotyledonous plant that belongs to the family Convolvulaceae. Its large, starchy, sweet-tasting, tuberous roots are an important root vegetable (Loebenstein and Thottappilly, 2009). The origin of sweet potato has been traced to Central or South America based on several lines of evidence. Phylogenetic analyses have shown that the closest wild relatives of sweet potato occur in the tropical Americas, suggesting an origin there (Roullier *et al.*, 2013). Additionally, sweet potato remnants found in Peruvian archaeological sites dated to 8,000-10,000 years ago provide evidence of early domestication in South America (Zhang *et al.*, 2000).

After its initial domestication, sweet potato was spread by Native American cultures throughout the American tropics. It was later introduced to Europe by Columbus in 1492 and subsequently transported from Spain to Africa, Asia, and the Pacific Islands by early explorers and traders (Loebenstein and Thottappilly, 2009). Sweet potato was introduced to China in the late 16th century and today China is the world's largest sweet potato producer, accounting for over 80% of global output (Zhang *et al.*, 2000). Beyond China, sweet potato is currently grown throughout tropical and warmer temperate regions for its edible tubers. Major producers include Tanzania, Nigeria, Uganda, Vietnam, North Korea, Indonesia, India and Brazil (Loebenstein and Thottappilly, 2009). It has become an

important food crop in many developing countries due to its adaptability, high yields, and nutritional benefits.

In summary, phylogenetic and archaeological evidence indicates sweet potato was likely domesticated in Central or South America thousands of years ago. It was later spread by humans throughout the tropics and is now an important crop with a pantropical distribution thanks to its versatility and productivity as a food source (Roullier *et al.*, 2013).

2.2 PHYSIOLOGICAL DESCRIPTION OF SWEET POTATO PLANT

Sweet potato (*Ipomoea batatas*) is a perennial plant in the morning glory family Convolvulaceae (Kays, 2011). It has a vigorous trailing vine that can reach over 5 meters in length if left unsupported (Loebenstein and Thottappilly, 2009). The stems and leaves of sweet potato plants exhibit considerable morphological diversity, but generally the stems are round or angular with finely grooved internodes while leaves are heart-shaped, palmately veined and come in a variety of shapes and sizes (Lebot, 2009).

The most economically important part of sweet potato is the storage roots which develop from adventitious roots just below ground level (Kays, 2011). These swollen roots can vary widely in shape (oblong, spherical, twisted), outer skin color (red, purple, brown, white) and flesh color (orange, yellow, white) between the many cultivars (Lebot, 2009). After 3-4 months of growth, the roots reach maturity and can weigh up to 5 kg each while yielding 7-13 edible roots per plant on average (Loebenstein and Thottappilly, 2009).

Sweet potato flowers have a trumpet-like shape with fused petals that open during the day in hues of purple, pink or white (Lebot, 2009). Pollen is released during a brief anthesis period and is primarily wind or insect mediated in most cultivars leading to the production of dry seed capsules containing 1-4 seeds (Kays, 2011). Natural seed set rates under field conditions are generally low, thus sweet potato is typically propagated clonally via storage roots, vines or shoot cuttings rather than seeds (Loebenstein and Thottappilly, 2009).

Overall, the trailing vines, varied leaves, seed capsules and edible storage roots allow the identification of sweet potato as a morphologically diverse *Ipomoea* species well suited as a food crop.

2.3 SCIENTIFIC CLASSIFICATION OF SWEET POTATO

The sweet potato (*Ipomoea batatas* (L.) Lam) belongs to the genus *Ipomoea*, in the family Convolvulaceae, order Solanales (Austin, 1988; Huaman, 1999). The genus *Ipomoea* consists of around 500-600 species of annual and perennial herbaceous vines and bushes, with a distribution concentrated in the tropics and subtropics (Austin, 1982). Species within this genus are commonly known as morning glories.

Ipomoea batatas is thought to be derived from the wild species *I. trifida*, which has similar storage roots and is native to the tropical Americas (Roullier *et al.*, 2013). Hybridization with other wild *Ipomoea* species like *I. tabascanana* may have also contributed to the origin of the sweet potato (Srisuwan *et al.*, 2006). However, the exact

wild progenitor is still unclear. Regardless of its origin, the cultivated sweet potato exhibits sufficient morphological and genetic differentiation from wild species to warrant its own Linnaean binomial - *Ipomoea batatas* (Lam.) (Huaman, 1999).

Within the species *I. batatas* there are thousands of cultivated varieties exhibiting variation in traits such as storage root shape, size, colour, nutrient composition, and more (Lebot, 2009). This variation reflects the plant's phenotypic plasticity as well as centuries of selective breeding by indigenous peoples across the world following the global dispersal of sweet potato from its South American centre of origin (Roullier *et al.*, 2013).

In summary, modern taxonomic classification places sweet potato in the genus *Ipomoea*, family *Convolvulaceae*. Its likely ancestors are wild *Ipomoea* species from the Americas, but after domestication and global distribution, *I. batatas* evolved into a distinct, economically important crop species (Roullier *et al.*, 2013).

Kingdom: *Plantae*

Division: *Magnoliophyta*

Class: *Eudicots*

Sub-class: *Asterids*

Order: *Solanales*

Family: *Convolvulaceae*

Genus: *Ipomoea*

Species: *I. batatas*

Binomial name: *Ipomoea batatas* (L.) Lam

2.4 NUTRITIONAL COMPOSITION OF SWEET POTATO PLANT PARTS

Among sweet potato (*Ipomoea batatas*) plant parts, the storage roots have received the most nutritional analysis while the foliage is less studied but still demonstrates promise as a nutrient source. On a dry weight basis, sweet potato leaves contain high protein (27-34%), moderate energy (290-319 kcal/100g) and extremely high provitamin A carotenoids as β -carotene equivalents (Rubaihayo *et al.*, 2008). The leaves offer comparable or greater protein, energy, minerals (iron, calcium, zinc) and vitamin C levels than other staple foliage crops like cassava or taro leaves (Islam, 2006).

In contrast, sweet potato vines and stems are lower in protein (10-16%), energy density (239-270 kcal/100g) and provitamin A, but still provide antioxidants like phenolic acids and vitamin C, as well as various bioactive proteins and peptides (Jung *et al.*, 2011). Studies utilizing sweet potato vine extracts have shown antimicrobial, anticancer, antioxidant, antihypertensive, anti-inflammatory effects and more in vitro and in vivo (Jung *et al.*, 2011; Jung *et al.*, 2013).

Finally, the storage roots exhibit wide variation but typically contain 20-30% starch, are moderately high in fibre, vitamin C, potassium, with provitamin A levels that differ

among orange-fleshed (high β -carotene) and white-fleshed (low carotenoids) cultivars (Teow *et al.*, 2007). Protein content in roots is just 1-2%, but certain varieties have shown elevated bioactive proteins with trypsin inhibitory, cancer cell suppressive or antidiabetic activity in vitro (Mukherjee *et al.*, 2016).

In conclusion, all plant parts of *Ipomoea batatas* provide some nutritional value, but leaves offer very high vitamin, protein and mineral content, vines contain a variety of bioactive phytochemicals, while storage roots are primarily composed of starch and carotenoids levels that vary among cultivars.

2.5 LEAF PROTEIN CONCENTRATE (LPC)

Leaf protein concentrate is a concentrated protein source derived from the leaves of plants and green leafy vegetables. It represents an abundant and potentially inexpensive protein option, especially in tropical regions where leaves are plentiful. The amino acid profile of leaf protein concentrate is well-balanced compared to established dietary requirements (Pirie, 1987). While humans do consume some protein directly from edible leafy vegetables, our digestive system could not handle the immense volume of leaves needed to meet our protein needs through leaf vegetables alone (Bray, 1988). This is where leaf protein concentrate comes in - it allows the nutritional value of leaves to be concentrated and consumed in a more manageable form.

The concentrated leaf protein product has a green color and does not present palatability issues when incorporated into mixed feeds. However, at higher inclusion levels in poultry

diets, it may suppress feed intake and increase wet droppings (Kohler and Bickoff, 1987). Interestingly, the carcasses of poultry raised on diets containing leaf protein concentrate often take on a yellow hue due to the presence of carotenoids like vitamin A precursor molecules (Aletor and Agbede, 2003). Despite some potential drawbacks, leaf protein concentrate remains an intriguing alternative protein source worthy of investigation, especially given its abundance and affordability in certain regions of the world.

2.5.1 EXTRACTION AND PURIFICATION TECHNIQUES FOR LEAF PROTEIN CONCENTRATE

The extraction and purification processes of leaf protein concentrate are crucial in obtaining a concentrated and purified protein product. Several techniques have been developed and optimized over the years to maximize protein yield and quality.

One of the most common methods is the alkaline extraction process. It involves treating the leaf material with a sodium or potassium hydroxide solution to solubilize the leaf proteins (Moure *et al.*, 2006). The extract is then precipitated by adjusting the pH to the isoelectric point of the proteins, typically around pH 4-5. This causes the proteins to aggregate and separate from the soluble non-protein components. The precipitated proteins are then recovered, washed, and dried to obtain the LPC (Moure *et al.*, 2006).

Another technique is the use of enzymes for protein extraction. Proteolytic enzymes like papain, bromelain, or alkaline proteases can be used to hydrolyze the leaf proteins, releasing them from the cellular matrix. The enzymatic treatment is followed by

precipitation and purification steps similar to the alkaline extraction method (Knuckles *et al.*, 2001)

Heat-based extraction methods have also been explored. These involve heating the leaf material in water or buffer solutions to denature and solubilize the proteins, which are then recovered by precipitation (Tangka *et al.*, 2003). However, the high temperatures can potentially cause protein degradation and affect the nutritional quality of the LPC (Bals *et al.*, 2012).

More recently, researchers have explored the use of ionic liquids for LPC extraction. Ionic liquids are salts that remain liquid at relatively low temperatures and can effectively solubilize and extract proteins from plant biomass (Desai *et al.*, 2016). This method has shown promise in achieving high protein yields and reducing the use of harsh chemicals (Nayak *et al.*, 2021).

Regardless of the extraction method, the purification of LPC often involves additional steps to remove unwanted components, such as lipids, pigments, and phenolic compounds. These can include solvent extraction, adsorption techniques, or membrane filtration processes (Urribarrí *et al.*, 2005; Mimouni *et al.*, 2019).

The choice of extraction and purification techniques depends on factors like the leaf source, desired protein quality, and economic feasibility. Continuous research efforts are focused on optimizing these processes to improve the efficiency, sustainability, and nutritional properties of LPC as a valuable plant-based protein source.

2.5.2 Amino Acid Composition and Protein Quality of Leaf Protein Concentrate

Leaf protein concentrate (LPC) is increasingly recognized as a promising plant-based protein source due to its favorable amino acid composition and high protein quality. The specific amino acid profile of LPC can vary depending on the leaf source and extraction method, but it generally exhibits a well-balanced array of essential and non-essential amino acids.

Several studies have analyzed the amino acid composition of LPCs derived from various leafy biomass sources. For instance, Bals *et al.* (2012) reported that LPC obtained from alfalfa leaves contained all essential amino acids, with relatively high levels of lysine, leucine, and phenylalanine. Similarly, Mimouni *et al.* (2019) found that sugar beet LPC had a well-balanced essential amino acid content, comparable to the FAO/WHO reference protein.

In terms of protein quality, LPC has consistently demonstrated high values in various evaluation methods. The Protein Digestibility Corrected Amino Acid Score (PDCAAS), which considers both amino acid composition and digestibility, is commonly used to assess protein quality. Knuckles *et al.* (2001) reported PDCAAS values of 0.92-1.0 for LPCs from different leaf sources, indicating excellent protein quality comparable to or even surpassing some animal-derived proteins.

The biological value (BV), which measures the efficiency of protein utilization by the body, is another important parameter. LPCs have exhibited high BV values, ranging from

0.7 to 0.9, depending on the leaf source and processing conditions (Moure *et al.*, 2006). These values are similar to or higher than those of many conventional plant proteins, such as soy protein isolate (Tangka *et al.*, 2003).

Furthermore, LPCs have been found to be rich in essential amino acids that are often limiting in plant-based diets, such as lysine and methionine (Urribarrí *et al.*, 2005). This makes LPC a valuable complementary protein source when combined with other plant proteins, improving the overall amino acid balance and nutritional quality of the diet.

However, it is important to note that the amino acid composition and protein quality of LPC can be influenced by factors such as leaf source, growth conditions, processing methods, and the presence of anti-nutritional factors (Desai *et al.*, 2016). Careful selection of leaf sources and optimization of extraction and purification techniques are crucial to maximize the nutritional value of LPC.

Table 2.1: Proximate Composition (g/100gDM) of four Leafy Vegetables

Vegetable species	Family	DM (%)	CP (%)	EE (%)	CF (%)	Ash (%)	NFE (%)	GE
<i>S. Africana</i>	Solanaceae	96.4±0.3	46.1±1.2	8.7±0.1	1.3±0.1	19.4±0.2	20.3	1798
<i>A. hybridus</i>	Amaranthaceae	95.5±0.2	35.1±1.3	5.6±0.3	1.1±1.4	22.3±0.1	31.4	1584
<i>T. occidentalis</i>	Curcubitaceae	97.3±0.3	54.9±1.3	11.9±0.2	1.8±0.3	11.4±0.4	17.3	2077
<i>V. amygdalina</i>	Compositaceae	94.5±0.4	52.2±2.4	5.6±0.37	1.5±0.6	9.5±0.1	25.7	1896
	MEAN	96.0	47.2	7.1	1.4	15.7	23.7	439
	S>D	1.2	8.8	3.0	0.3	6.2	6.6	0.3
	CV(%)	1.3	18.6	37.9	20.7	39.4	28.2	68.0

Source: Aletor *et al.* (2002)

2.5.3 Potential Use of Leaf Protein Concentrate in Food and Feed Applications

Leaf protein concentrate (LPC) has garnered significant interest as a sustainable and nutrient-rich ingredient for both food and feed applications. Its unique properties and favorable nutritional profile make it a promising alternative to conventional protein sources.

In food applications, LPC has been explored as a functional ingredient in various products, such as bread, pasta, and meat analogues. Farzana *et al.* (2017) studied the incorporation of LPC in bread formulations, reporting improved protein content and sensory acceptability up to a certain level of substitution. Similarly, Arora and Srivastava (2002) investigated the use of LPC in extruded snack products, observing enhanced nutritional value and textural characteristics.

LPC has also shown potential as a protein-enriching ingredient in traditional foods and beverages. Moure *et al.* (2006) demonstrated the successful incorporation of LPC into dairy products, such as yogurt and cheese, without compromising sensory attributes. Additionally, Bals *et al.* (2012) explored the use of LPC in plant-based milk alternatives, improving their protein content and nutritional profile.

Beyond its direct use as an ingredient, LPC can also serve as a valuable source of bioactive compounds and functional proteins. Researchers have investigated the extraction and purification of specific proteins from LPC, such as enzymes, antimicrobial

peptides, and antioxidants, for various applications in the food and pharmaceutical industries (Nayak *et al.*, 2021).

In the animal feed sector, LPC has been extensively studied as a protein-rich supplement for livestock and aquaculture. In 2001, Knuckles *et al.*, reported promising results when incorporating LPC into poultry and swine diets, with improved growth performance and feed conversion efficiency. Furthermore, Mimouni *et al.* (2019) highlighted the potential of LPC as a sustainable fishmeal replacement in aquaculture feeds, providing a valuable source of plant-based protein.

However, it is important to consider the potential limitations and challenges associated with the use of LPC in food and feed applications. These may include factors such as off-flavors, color issues, and the presence of anti-nutritional factors, which can impact sensory properties and digestibility (Becker, 2007). Additionally, economic and scalability considerations must be addressed to ensure the feasible and cost-effective production of LPC on a commercial scale.

Continued research efforts are focused on optimizing processing techniques, addressing potential limitations, and exploring novel applications to fully harness the benefits of this nutrient-rich plant-based protein source.

2.6 SWEET POTATO TUBER PROCESSING

Sweet potato (*Ipomoea batatas*) is a widely consumed root vegetable known for its nutritional value and versatility in culinary applications. The peeling process is an essential step in preparing sweet potatoes for various uses, and the choice of peeling technique can significantly impact the quality of the tuber.

- Traditional Peeling Methods:

1. Manual Peeling: This method involves manually removing the skin or peel using a knife or peeler. While labor-intensive, manual peeling allows for precise control and minimizes waste (Truong *et al.*, 2019). However, it can be time-consuming and poses risks of injury.

2. Abrasive Peeling: This technique utilizes abrasive surfaces, such as rotating brushes or drums, to remove the peel through mechanical friction (Srichuwong *et al.*, 2012). Abrasive peeling is often faster than manual peeling but may result in higher product loss and potential damage to the tuber flesh.

- Modern Peeling Techniques:

1. Steam Peeling: This method involves exposing the sweet potatoes to high-pressure steam, which causes the skin to loosen and separate from the flesh (Loh *et al.*, 2014). Steam peeling is efficient, hygienic, and can preserve nutrients while minimizing waste.

2. Caustic Peeling: In this process, sweet potatoes are treated with caustic solutions, such as sodium hydroxide or lye, which break down the skin and facilitate its removal (Truong *et al.*, 2019). Caustic peeling is effective but requires careful control of chemical concentrations and proper rinsing to ensure food safety.

3. Laser Peeling: This advanced technique uses high-intensity laser beams to precisely remove the skin without damaging the underlying flesh (Kondjoyan and Daudin, 2013). Laser peeling offers high accuracy and minimal product loss but can be expensive and energy-intensive.

- Impact on Tuber Quality:

The choice of peeling technique can have various impacts on the quality of the sweet potato tuber:

1. Nutrient Retention: Certain peeling methods, such as steam peeling and manual peeling, can better preserve the nutritional content of the tuber by minimizing the loss of vitamins, minerals, and bioactive compounds present in the skin (Loh *et al.*, 2014; Srichuwong *et al.*, 2012).

2. Physical Characteristics: Peeling techniques can affect the appearance, texture, and overall physical quality of the sweet potato flesh. Abrasive peeling may cause surface damage, while chemical treatments can alter the color and texture (Truong *et al.*, 2019).

3. **Microbial Safety:** Proper peeling techniques, coupled with good hygiene practices, are essential for reducing the risk of microbial contamination and ensuring food safety (Kondjoyan and Daudin, 2013).

4. **Waste Generation:** Different peeling methods can result in varying levels of product loss and waste generation, impacting the overall efficiency and sustainability of the process (Loh *et al.*, 2014).

In addition to the peeling technique, factors such as sweet potato variety, maturity stage, and storage conditions can also influence the effectiveness and impact of the peeling process.

Research is still carried out to explore and optimize peeling techniques to achieve the desired balance between efficiency, product quality, and environmental sustainability, while ensuring food safety and meeting consumer preferences.

2.6.1 Optimization of Sweet Potato Processing Parameters to Maintain Desirable Tuber Quality

The processing of sweet potato tubers can significantly impact their desirable properties, such as color, texture, flavor, and nutritional value. Optimizing the processing parameters is crucial to maintain these desirable qualities and maximize the potential of sweet potato tubers.

- **Thermal Processing:**

Heat treatment is a common processing step for sweet potatoes, often involving cooking, baking, or frying. The temperature, duration, and method of thermal processing can influence the tuber's properties:

1. Color: High temperatures and prolonged heating can lead to the degradation of pigments, such as anthocyanins, resulting in color changes (Mei *et al.*, 2019). Optimizing temperature and time can help preserve the vibrant orange or purple hues associated with certain sweet potato varieties.
 2. Texture: Thermal processing can affect the texture of sweet potato tubers by altering the starch structure and cell wall composition (Wang *et al.*, 2016). Appropriate temperature and time combinations can ensure the desired tenderness or firmness, depending on the intended application.
 3. Nutritional Value: Heat can degrade certain vitamins and bioactive compounds, such as vitamin C and polyphenols (Truong *et al.*, 2018). Careful control of temperature and processing duration can help retain these beneficial nutrients.
- Drying and Dehydration:

Sweet potato tubers are often dried or dehydrated for long-term storage, snack production, or the creation of flour or powders. The drying parameters, including temperature, air flow, and moisture content, play a crucial role in preserving the tuber's desirable properties:

1. Color: High drying temperatures can lead to enzymatic browning and non-enzymatic browning reactions, affecting the color of the dried product (Suna *et al.*, 2014). Optimizing the drying temperature and employing pretreatments like blanching or sulfiting can help maintain the desired color.
 2. Texture: Improper drying conditions can result in tough, fibrous, or brittle textures (Huang *et al.*, 2019). Controlling the drying rate and final moisture content can ensure the desired crispness or softness of the dried product.
 3. Nutritional Value: Drying can concentrate certain nutrients, such as dietary fiber and minerals, but may also lead to the loss of heat-sensitive vitamins and antioxidants (Huang *et al.*, 2019). Optimizing drying conditions and employing techniques like vacuum or freeze-drying can help preserve these valuable compounds.
- Pretreatments and Additives:

Various pretreatments and the addition of specific compounds can be employed to enhance the stability and desirable properties of sweet potato tubers during processing:

1. Blanching: This pretreatment involves brief exposure to hot water or steam, which can inactivate enzymes responsible for browning and textural changes (Truong *et al.*, 2019).
2. Sulfiting: The addition of sulfites or sulfur dioxide can inhibit enzymatic browning and preserve the color of sweet potato products (Suna *et al.*, 2014).

3. Antioxidants: Incorporating natural antioxidants, such as ascorbic acid or plant extracts, can help prevent oxidation and maintain the nutritional value and color of processed sweet potato products (Mei *et al.*, 2019).
 4. Texture Modifiers: The addition of hydrocolloids, gums, or other texture-modifying agents can help maintain the desired texture and mouthfeel of sweet potato-based products during processing and storage (Wang *et al.*, 2016).
- Optimization Strategies:

To optimize the processing parameters for sweet potato tubers, researchers employ various strategies, including experimental design, response surface methodology, and mathematical modeling (Truong *et al.*, 2018; Huang *et al.*, 2019). These techniques allow for the systematic evaluation of multiple factors and their interactions, enabling the identification of optimal processing conditions that maintain the desired color, texture, flavor, and nutritional properties.

Continuous research efforts are focused on developing innovative processing technologies, such as ultrasound-assisted drying, high-pressure processing, and pulsed electric field treatment, to enhance the quality and functionality of sweet potato-based products while minimizing nutrient losses and preserving their desirable attributes (Mei *et al.*, 2019; Wang *et al.*, 2016).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location and Duration of Study

The experimental work was carried out in the main laboratory of the Faculty of Agriculture, University of Benin, Ugbowo Campus, Benin City, Edo State, Nigeria. University of Benin is located between Latitude 6⁰30' N of the Equator, and Longitude 5⁰40' and 6⁰E of the Greenwich Meridian in the forest zone, with an average temperature of 27.6⁰C (NAA, 2014). The research was conducted in two phases: firstly, calibration was carried out using five (5) trials. The essence of these trials was to get acquainted with the proper production and storage methods of leaf protein concentrate and peeled tuber. In the second phase, development of feed grades (25%, 50% and 75%) using Sweet potato (*Ipomoea batatas L.*) leaf protein concentrate and peeled tuber, followed by the determination of their chemical compositions such as proximate (dry matter, crude protein, crude fibre, ether extract, ash and nitrogen free extract) and some minerals.

3.2 Experimental Materials

Freshly harvested Sweet potato (*Ipomoea batatas L.*) leaves, Sweet potato peeled tubers, sensitive scale, stainless steel pot, grinding machine, sieve cloth, plastic bowls, spoons, knives, and heat source.

3.3 Experimental Design

Feed grades shall be developed using Sweet potato leaf protein concentrate (LPC) and peeled tuber in the following ratios:

Treatment 1: 100% LPC and 0% Peeled tuber

Treatment 2: 75% LPC and 25% Peeled tuber

Treatment 3: 50% LPC and 50% Peeled tuber

Treatment 4: 25% LPC and 75% Peeled tuber

Treatment 5: 0% LPC and 100% Peeled tuber

Ground leaf protein concentrate and peeled tubers were mixed together at different ratios. 50ml of water was added to the mixture and allowed to stay for 24 hours before drying. The resultant dried products were stored in airtight containers for chemical analysis.

3.4 Preliminary Trials

Five (5) preliminary trials were carried out before the final production, which was done to serve as a guide, and to effectively standardize the process, while helping to get acquainted with the process and eliminate all controllable errors encountered.



Fig 3.1: Preliminary trial for SPLPC processing tuber



Fig 3.2: Processing of Sweet potato peeled

3.5 Calibration Procedure

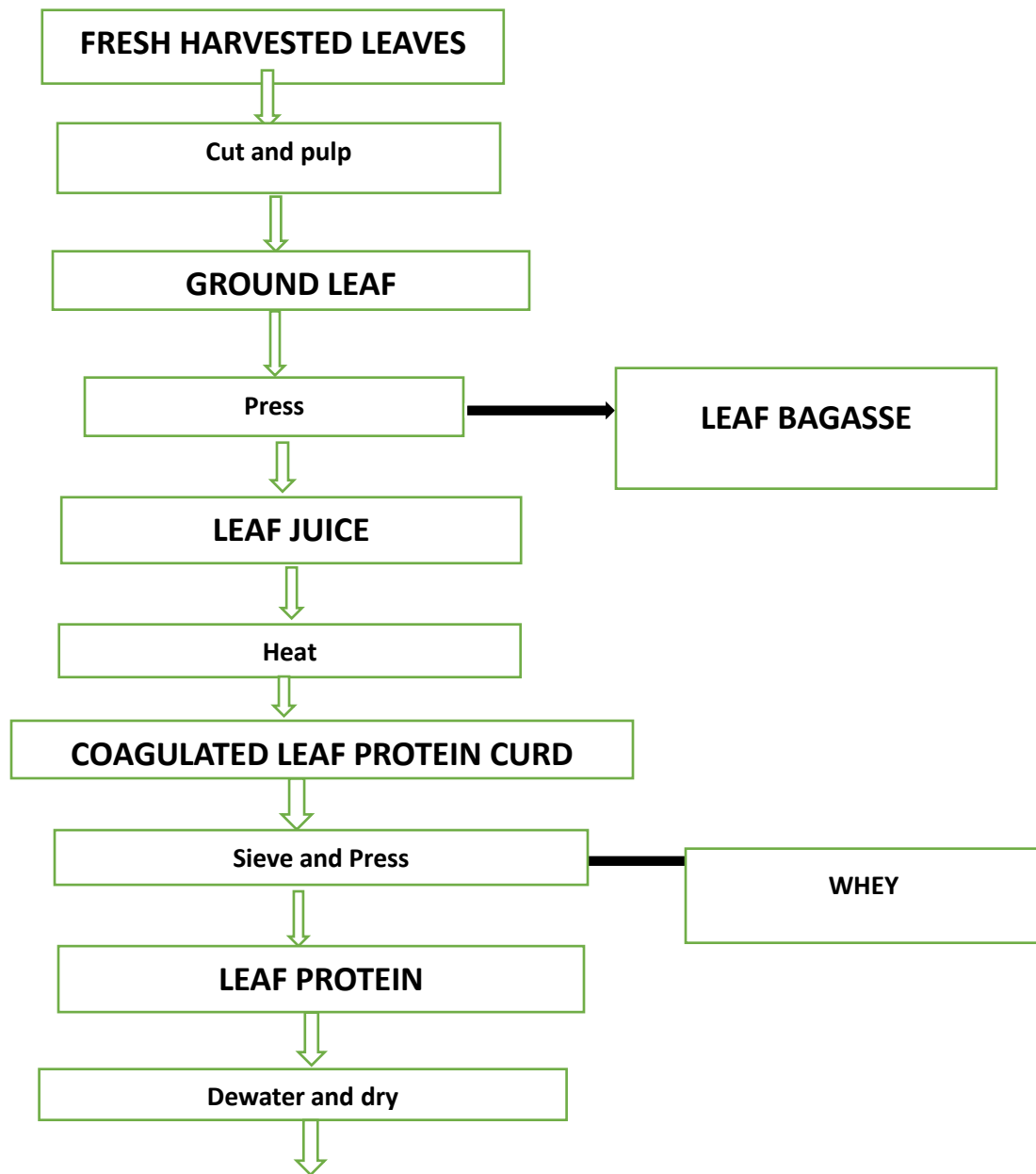
Fresh potato leaves were harvested early in the day before sunrise. They were immediately taken to the laboratory for processing to prevent wilting. The leaves were thoroughly washed to remove all extraneous materials before sun-drying to remove moisture. Then a varying but known sample was weighed for each trial, and this was ground into slurry with a slightly varying but known amount of water. Then the juice

obtained from these samples was used to produce leaf protein curds using the heat coagulation method. The leaf protein curd was then sieved and pressed as in Figure 3.2 (Pirie, 1987; Nwokoro, 2017) followed by dewatering and drying to obtain leaf protein concentrate. The yield was recorded after drying.

Fresh potato tubers were bought from the market. The potato was weighed and then separated into two component parts: tuber peel and peeled tuber, making sure to only obtain the portion of the tuber that wasn't rotten or affected by pests and diseases. The peeled tubers were cut into slim sizes and were dried under the sun for a known number of days. Then the peeled tubers were taken for grinding to obtain products for drying and reconstitution. The yield was recorded after drying.



Fig 3.3: Extraction of leaf juice from ground leaf of sweet potato



LEAF PROTEIN

Figure 3.4: Flow chart of the production of leaf protein concentrate.

Sources: Pirie (1987), as modified by Nwokoro (2015).

3.6 Precautions taken during the Production of Leaf Protein concentrate and Peeled tuber

- Fresh potato leaves were obtained from green, healthy plants.
- Leaves were immediately taken to the laboratory for processing in order to avoid leaf wilting.
- Matured leaves free of physical injuries were used.
- The leaves were thoroughly washed to remove dirt and dust which could have altered the result.
- The sieve cloth had a very small pore in order to prevent fibre from passing through.
- Bagasse was tightly pressed during separation from juice until there was no juice in it.
- The juice was removed from the heat source a few minutes after boiling to avoid burning the cord.
- The LPC was rather sun-dried than oven-dried.
- After extracting the LPC, no moisture came in contact with it until reconstitution.
- Healthy-looking sweet potato was obtained from the market.
- After each use, all processing equipment were thoroughly washed before re-use to prevent contamination and guarantee result.

3.7 PRODUCTS HANDLING

The following products were obtained during processing:

1. Bagasse
2. Curd
3. Whey

1. Bagasse: This is the fraction obtained in the processing stage after blending and sieving the slurry. It was sun-dried and weighed to a constant weight before analysis.

2. Curd: The curd was collected after separation and weighed. Then it was sun-dried properly until it became flaky.

3. Whey: This is the liquid fraction after the curd has been removed. It was collected

and stored in bottles.



Fig 3.5: By-products obtained while processing the SPLPC (Bagasse)

3.8 CHEMICAL ANALYSIS

The LPC and potato peel resulting combination was analyzed proximately and also some mineral content of the combination was analyzed. Fifteen samples were analyzed at different combination ratios.

3.8.1 Moisture Content (MC) Determination

Materials used: Sensitive scale, oven, crucible and Desiccators.

Procedure

A portion of the sample was collected and weighed in two silica dishes that have been previously pre-dried and weighed. Then it was put in the oven at 100⁰C for 24 hours and then dried to constant weight. The samples were then cooled in a desiccator before weighing again until a constant weight was obtained.

Calculation:

Weight of moisture = weight of sample before drying – weight of sample after drying

% moisture = (weight of moisture)/weight of sample * 100

Dry matter = 100 - % moisture

3.8.2 Crude Protein Determination

A portion of the combined sample was weighed and transferred into clean digestion flasks. Copper catalyst plus sodium sulphate was then added to raise the boiling point. 30ml of concentrated sulphuric acid was added to the digestion flask containing the other mixture, and the sample digested for two hours. The flask was cooled and diluted with water, and was made to 100ml in a volumetric flask. 20ml of 2% boric acid plus indicator was pipetted into a 100ml Erlenmeyer flask. The 100ml flask was then placed under the receiving tube of the distillation unit in a way that the end of the tube is below the level of the H_3BO_3 . 10ml aliquot of the sample was then pipetted into the distillation unit and 100ml of 40% NaOH was added. The samples were distilled with standard HCL (0.01N) until the blue colour disappeared. A blank determination was first carried out, and the Crude Protein value was determined using the following formula:

Calculation:

$$\% \text{ Nitrogen} = \text{Normality of acid} * (14/1000) * \text{volume of acid} * (100/5) * (100/\text{weight of sample})$$

$$\% \text{ Crude protein} = \% \text{ Nitrogen} * 6.25$$

3.8.3 Crude Fibre (CF) Determination

A portion of the combined sample was weighed into a round bottom flask. 100ml of crude fibre reagent that has been boiled was added, and then the beaker placed on the crude fibre apparatus which has been presented to maintain steady boiling. The content was filtered under suction on a piece of close texture linen after refluxing after 1 hour. The residue was rinsed with boiling water until it was free of acid. Also, NaOH (sodium hydroxide) solution which had been previously boiled was added and filtered hot while using a Whatman filter paper, and the residue was allowed to drain and transferred to a pyrex heater and dried, weighed and ashed. The residue was cooled in a desiccator and weighed after 1 hour. The loss in weight due to ashing was calculated as the crude fibre content.

Calculation:

Sample weight = A

Weight before ashing = P

Weight after ashing = Z

% Crude fibre = $(P - Z)/A * 100$

3.8.4 Ash Determination

A portion of the combined sample was weighed and put in a weighed crucible and ignited at 550⁰ for 6 hours in the furnace for ashing. Then the samples were removed

and allowed to cool in a desiccator for about 30 minutes, then re-weighed and the value was calculated.

Calculations:

Sample weight = A

Sample weight before ashing = P

Sample weight after ashing = Z

% Ash = $(P - Z) / A * 100$

3.8.5 Ether Extraction (EE)

A portion of the combined sample was weighed into a fat-free filter paper. It was then folded tightly and placed in the extractor; petroleum ether was then added until is siphoned over. More ether was added until the 300ml barrel was half-filled; the condenser was replaced. The control was adjusted on the apparatus so that the others boiled gently, and it was left to siphon over for 2 hours. The apparatus was washed after 3 hours because it was expected that, by this time, all the fat present in the sample would have been extracted. The flask was then detached when the ether was short of siphoning over. The barrel content was drained properly into the bottle and the filter paper removed and dried. The flask was detached, while the samples were removed and dried in an oven to constant weight.

Calculation:

$$\%EE = (\text{weight of oil}) / (\text{weight of sample}) * 100$$

3.8.6 Nitrogen Free Extract (NFE)

This was determined by the subtraction of the addition of % ash, ether extract, crude protein, and crude fibre from 100. The difference is the Nitrogen Free Extract.

$$NFE = 100 - (\%CP + \%EE + \%CF + \%Ash)$$

3.9 MINERAL ANALYSIS

Minerals were analyzed after first dry-ashing 1g of the combined sample at 550⁰ in a Muffle furnace and dissolved in de-ionized water to standard volume. Sodium and Potassium were determined by flame photometry and phosphorus by vanadomolybdate method (AOAC, 2010). Magnesium, calcium, manganese, iron, zinc and copper were determined using an Atomic Absorption Spectrophotometer.

3.10 STATISTICAL ANALYSIS

Data collected from the study were subjected to analysis of variance (ANOVA) using the GENSTAT statistical package at 5% ($p < 0.05$). The means with significant difference were separated using the same statistical package.

CHAPTER FOUR

4.0 RESULTS

4.1 Proximate composition of feed resources developed using Sweet potato Leaf Protein Concentrate (SPLPC) and Peeled Tuber

The proximate composition of a feed resource developed using Sweet potato leaf protein concentrate and Peeled Tuber is shown in Table 4.1. Results showed that the dry matter content of the feed resource are not significantly different across treatments ($p > 0.05$). 25LPC75PT (90.68%) and 50LPC50PT (89.29%) had the highest recorded values for the treatments. The crude protein content of the feed resources ranged from 7.57% to 39.84%, with each treatment being significantly different from the other ($p < 0.05$). Results showed that the crude fibre content was significantly different across treatments. The highest (7.93) and lowest (1.11) crude fibre values were recorded for 100PT and 100SPLPC. For Ether extract content, 50LPC50PT and 75LPC25PT treatments were not significantly different from each other ($p > 0.05$). They were, however, significantly different across the other treatments ($p < 0.05$). Results for the ash content showed that at 5.83%, 100SPLPC was significantly different from the other treatments ($p < 0.05$). However, 100PT and 25LPC75PT were not significantly different from each other ($p > 0.05$). The NFE content across the treatments ranged from 43.29% to 70.83%, with each treatment being significantly different across treatments ($p < 0.05$).

Table 4.1: Proximate composition of feed resources developed using Sweet potato Leaf Protein Concentrate and Peeled Tuber

Parameters	100PT	100SPLPC	25LPC75PT	50LPC50PT	75LPC25PT	SEM
Dry matter (%)	89.86 ^a	90.25 ^a	90.68 ^a	89.29 ^a	89.51 ^a	0.54
Crude protein (%)	7.57 ^c	39.84 ^a	13.90 ^d	25.48 ^c	30.57 ^b	0.38
Crude Fibre (%)	7.93 ^a	1.11 ^e	5.52 ^b	3.67 ^c	2.17 ^d	0.24
Ether extract (%)	5.30 ^d	9.93 ^a	6.73 ^c	8.10 ^b	8.54 ^b	0.28
Ash (%)	8.37 ^a	5.83 ^c	8.19 ^a	7.59 ^{ab}	6.91 ^b	0.25
NFE (%)	70.83 ^a	43.29 ^e	65.66 ^b	55.16 ^c	51.81 ^d	0.75

^{abcde} Means on the same row with different alphabets are significantly different at p<0.05 probability level.

SEM = Standard error of mean

PT = Peeled tuber

SPLPC = Sweet potato leaf protein concentrate

LPC = Leaf protein concentrate

NFE = Nitrogen free extract

4.2 Mineral composition of feed resources developed using Sweet potato Leaf Protein Concentrate and peeled tuber

Table 4.2 shows the mineral composition of a feed resource developed using Sweet potato leaf protein concentrate and peeled tuber. Results showed that the Na content was significantly different across treatments ($p < 0.05$), with the highest (290.70mg/g) and lowest (25.60%) being 100PT and 100SPLPC, respectively. The calcium content ranged from 939.00mg/g to 2027.00mg/g across treatments, with the highest (100PT) and lowest (100SPLPC) being significantly different from the other treatments ($p < 0.05$). Results showed that the calcium content of 100PT and 25LPC75PT were not significantly different from each other ($p > 0.05$). However, the two treatments were significantly different from the other treatments ($p < 0.05$). The Mg content of the feed resources was significantly different across treatments ($p < 0.05$), with the highest and lowest being 100PT and 100SPLPC, respectively. Results showed that the P content of 100SPLPC and 75LPC25PT were not significantly different ($p < 0.05$), while both treatments were significantly different across the other treatments. The Fe content of the feed resources was significantly different across treatments ($p < 0.05$), with the highest (744.40mg/g) and lowest (144.50mg/g) being 100PT and 100SPLPC, respectively. The Mn content ranged from 33.07mg/g to 86.68mg/g, with 100PT and 75LPC25PT being the highest and lowest, respectively. 100PT and 25LPC75PT were both significantly different across treatments ($p < 0.05$). Results showed that the Zn content of the feed resources varied from 7.54mg/g to 70.41mg/g. While 100PT and 25LPC75PT were not statistically

significant from each other ($p > 0.05$), they were both significant across the other treatments.

Table 4.2: Mineral composition of a feed resource developed using Sweet Potato Leaf Protein Concentrate and Peeled Tuber

Parameters	100PT	100SPLPC	25LPC75PT	50LPC50PT	75LPC25PT	SEM
Na (mg/g)	290.70 ^a	25.60 ^e	242.00 ^b	171.40 ^c	96.50 ^d	12.55
Ca (mg/g)	2027.00 ^a	939.00 ^d	1640.00 ^b	1440.00 ^{bc}	1224.00 ^c	68.94
K (mg/g)	9893.00 ^a	2326.00 ^d	10194.00 ^a	7584.00 ^b	4371.00 ^c	415.52
Mg (mg/g)	1333.60 ^a	235.30 ^e	1029.50 ^b	753.40 ^c	431.40 ^d	51.94
P (mg/g)	2671.00 ^a	314.00 ^d	1422.00 ^b	969.00 ^c	569.00 ^d	86.53
Fe (mg/g)	744.40 ^a	144.50 ^e	641.60 ^b	499.80 ^c	362.10 ^d	15.41
Mn (mg/g)	86.68 ^a	50.73 ^c	66.99 ^b	41.77 ^{cd}	33.07 ^d	3.67
Zn (mg/g)	70.41 ^a	7.54 ^d	69.52 ^a	47.76 ^b	27.76 ^c	4.71

^{abcde} Means on the same row with different alphabets are significantly different at p<0.05 probability level.

SEM = Standard error of mean

PT = Peeled tuber, SPLPC = Sweet potato leaf protein concentrate, LPC = Leaf Protein Concentrate, mg/g = milligram per gram

Na = Sodium, Ca = Calcium, K = Potassium, Mg = Magnesium, P = Potassium, Fe = Iron, Mn = Manganese, Zn = Zinc

CHAPTER FIVE

5.0 DISCUSSION

5.1 Proximate composition of feed grades developed using sweet potato leaf protein concentrate (SPLPC) and Peeled tuber

Results from the proximate analysis of the feed formulated from SPLPC and peeled tuber revealed that the crude protein of 100SPLPC was 39.84%. This result falls within the range reported by Agbonghae *et al.*, in 2019 on pawpaw LPC ($39.50 \pm 0.71\%$). As expected, the crude protein value also decreases with the addition of peeled tuber to the leaf protein concentrate, with the lowest crude protein value (7.57%) recorded from 100PT.

Crude fibre results were revealed to peak at 7.93% for 100PT. The lowest recorded result came from 100SPLPC at 1.11%. This result implies that crude fibre in the peeled tuber is significantly higher than that of leaf protein concentrate. The 1.11% crude fibre content for pure LPC is lower than the 1.8% reported by Akaeze *et al.*, for rubber in 2015. However, the 100PT is shown to be significantly higher in crude fibre than both peeled (1.31%) and unpeeled (3.09%) yam as reported by Akinola in 2020.

Ash content was reported to be as high as 8.37% in 100PT, and results have shown a trend of decreasing with the addition of leaf protein concentrate just like Cheeke *et al.*, reported in 1981. The ash content for 100PT is also significantly higher than the 2.32%

reported by Akinola on peeled yam in 2020. The 5.83% ash found in 100SPLPC is lower than the 8.80 ± 0.41 reported by Agbonghae *et al.*, in 2019.

The ether extract of the feed resource was highest in 100SPLPC and decreased as peeled tuber was added. The lowest value was recorded from 100PT. This significant difference may be as a result of the structural components of the leaf compared to the potato tuber. It's worth noting that the ether extract in 100SPLPC is a lot higher than the 4.15 ± 0.07 reported by Agbonghae *et al.*, on pawpaw leaf protein concentrate in 2019. However, it's less than the 10.7% *T. occidentalis* LPC reported by Adeyeye and Omolayo in 2011.

Results showed that the NFE was highest in 100PT and lowest in 100SPLPC. This is probably because of the protein present in SPLPC as compared to Peeled tubers. The NFE present in 100SPLPC is higher than the 41.75 ± 0.72 reported by Agbonghae *et al.*, on pawpaw leaf protein concentrate in 2019. However, it is lower than 47.2% from *Amaranthus cruentus* HH3 LPC as reported by Cheeke *et al.* (1981).

5.2 Mineral composition of feed grades developed using sweet potato Leaf Protein Concentrate (SPLPC) and Peeled Tuber

As shown in Table 4.2, results indicate that the quantity of macro and micro minerals present in the developed feed resource significantly decreased with the addition of SPLPC as a replacement for Peeled tuber at different replacement levels. This should be an indicator of which part of the plant is relatively richer in minerals. However, in the results of K and Zn, there was no significant difference in the mineral content of the feed

resource when 25% LPC was added to 75% peeled tuber ($p > 0.05$). This might be as a result of different factors like processing techniques, inherent nature of the minerals, as well as foreign materials that may have contaminated the developed feed resource. Results show that the most abundant minerals present in the feed resources are Ca, K, Mg and P. Zn, Mn, Fe and Na are present, but not as abundant as the others.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 SUMMARY

This research was carried out in two phases: First was calibration, which involved the extraction of Sweet potato leaf protein concentrate from leaf juice using heat coagulation method. This took five (5) trials. Second was the development of feed grades using Sweet potato leaf protein concentrate and Sweet potato peeled tuber, followed by the determination of their proximate and mineral composition.

From the results obtained, the 100SPLPC was significantly higher than the others in Crude protein content, but lower than the rest in crude fibre and ash content ($p < 0.05$). 100PT recorded the highest values for ash, NFE and crude fibre, but recorded low values for ether extract and crude protein. It's worth noting that the 50LPC50PT recorded balanced results across all mineral and proximate parameters.

6.2 CONCLUSION

The results from the study show that the developed feed resources have the potential to be used as feed for livestock. However, there may be some problems with the consistent availability of the feed because of the seasonality of the raw material and the relatively low yield of SPLPC compared to other parts of the plant. SPLPC and peeled tubers could be used as feed ingredients for livestock and serve as an alternative to conventional

feedstuff like soyabean meal, groundnut cake, and other protein feedstuffs in feed formulation considering the high protein content.

6.3 RECOMMENDATION

1. Research on more methods to improve LPC yield with a minimal effect on its chemical composition should be a priority.
2. The use of unconventional feedstuff as replacement feed ingredients should also be promoted, and more research and sensitization should be made in that regard.
3. The use of SPLPC and peeled tuber as a feed resource should be encouraged through awareness creation and sensitization of stakeholders in the feed industry.

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**DEVELOPMENT OF FEED GRADES FROM SWEET POTATO
(*Ipomoea batatas* L. Lam) LEAF PROTEIN CONCENTRATE AND
PEELED TUBER**

BY

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