PROXIMATE COMPOSITION, SAPONIN AND FLAVONOID CONTENT OF SOME LEGUMES

BY

IGHEDOSE Deborah Osemenel (Miss)
AGR2004307

DEPARTMENT OF ANIMAL SCIENCE
FACULTY OF AGRICULTURE
UNIVERSITY OF BENIN
BENIN CITY, EDO STATE

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CERTIFICATION

This is to certify that this project work was carried out by Deborah Osemenel IGHEDOSE with the Matriculation Number AGR2004307 of the Department of Animal Science, Faculty of Agriculture, University of Benin, Benin City, Nigeria.

Dr. Odafe-Shalome G.I.O

Project Supervisor

Signature and Date

Dr. N. C. Akaeze

Head of Department

Signature and Date

DEDICATION

This project is dedicated to God almighty for guiding and strengthening me always, to all my lecturers whose love and directives has helped me through my five years of study as well as to my treasured family for their endless support.

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ABSTRACT

This study investigated the proximate composition, saponin, and flavonoid contents of five legume species soybean (*Glycine max*), faba bean (*Viciafaba*), black gram (*Vignamungo*), jack bean (*Canavaliaensiformis*), and velvet bean (*Mucunasloanei*). The aim was to assess their nutritional value and bioactive potential for food and feed applications. Proximate parameters such as moisture, crude protein, ether extract, crude fiber, ash, and nitrogen-free extract (NFE) were analyzed using standard AOAC (2019) procedures. Results revealed notable variations among samples. Soybean had the highest protein (42.00%) and lipid (15.68%) contents, confirming its exceptional nutritive quality. Velvet bean showed the lowest moisture (1.30%), implying better storage durability, while black gram exhibited the highest NFE (62.04%), indicating that it is primarily carbohydrate-based. Jack bean and faba bean displayed moderate nutrient levels, whereas velvet bean offered a balanced profile of protein and carbohydrates. Quantitative Phytochemical findings revealed relatively high flavonoid and phenolic concentrations in soybean and jack bean, while velvet bean contained the highest saponin level. These bioactive components are associated with antioxidant and health-protective properties. The result suggest that underexploited legumes, particularly jack bean and velvet bean, could serve as nutritious alternatives to soybean when adequately processed to remove anti-nutritional compounds. Their wider use could expand protein options, enhance food security, and support sustainable agricultural systems.

CHAPTER ONE

1.0 INTRODUCTION

Legumes are a group of plants belonging to the family Fabaceae, characterized by their ability to produce seeds enclosed in pods. They are cultivated globally and represent one of the most important sources of dietary protein, carbohydrates, fiber, vitamins, and minerals for both human and animal nutrition. Legumes play a crucial role in food security, particularly in developing countries where they serve as affordable alternatives to animal protein sources. Beyond their nutritional significance, legumes also contribute to sustainable agriculture through their nitrogen-fixing ability, which enriches soil fertility reducing dependence on synthetic fertilizers (Stagnari*et al*., 2017).

According to the Food and Agriculture Organization (FAO), pulses are made up of about 20-25 percent protein by weight, which is double the protein content of wheat and triple that of rice, with low fat content and zero cholesterol. The nutritional value of legumes is determined by their proximate composition, which includes moisture content, crude protein, crude fiber, crude fat, ash, and carbohydrate content. Understanding the proximate composition of legumes is essential for assessing their potential as functional foods and for formulating balanced diets (Kumar *et al*., 2021).

In addition to macronutrients, legumes contain various bioactive compounds, including saponins and flavonoids, which have gained considerable attention due to their health-promoting properties. Saponins are glycosidic compounds present in pulses that possess several health benefits such as anti-inflammatory and anti-tumor properties, and can reduce glucose as well as lipid levels. Flavonoids, phenolic acids and procyanidins are the dominant phenolic compounds present in lentils, peas and common beans, with antioxidant activities, potential anti-carcinogenic and cardio-protective effects (Tungmunnithum*et al.,* 2018).

Jack bean (*Canavalia ensiformis*), velvet bean (*Mucuna sloanei*), black gram (*Vigna mungo*), soybean (*Glycine max*), and faba bean (*Vicia faba*) are widely cultivated legumes in tropical and subtropical regions. These legumes are known for their high protein content, drought tolerance, and ability to thrive in various soil conditions, making them valuable crops for enhancing food security and agricultural sustainability (Foyer *et al*., 2016; Singh *et al*., 2017). Soybean, in particular, is considered the most economically important legume globally, widely used in food, feed, and industrial applications due to its exceptional protein and oil content (Bellaloui *et al*., 2021). Black gram is a staple in South Asian cuisine and is valued for its protein and mineral content (Yadav *et al*., 2020). Faba bean has been recognized as a promising protein crop for both human consumption and animal feed in temperate regions (Crépon*et al*., 2010). White beans (common beans) are the third most important legume crop grown worldwide, after soybeans and peanuts, and will likely become an increasingly significant food source in Africa where they will represent an important legume supporting nutritional security.

Despite their widespread cultivation and consumption, according to FAO-assisted dietary guidelines evaluation, about 87% of approximately 100 countries recommend regular inclusion of pulses in the diet, but only in general terms without specifically pointing out their nutritional value or health benefits. Recent studies have emphasized on the need to analyze both the nutritional and phytochemical profiles of legumes to promote their incorporation into modern diets and animal feed formulations (Kumar *et al*., 2021; Singla&Panesar, 2022). Determining the proximate composition provides baseline information on the energy and nutrient density of these legumes, while quantifying saponin and flavonoid content helps evaluate their functional and therapeutic potential (Chung *et al*., 2022).

This project is therefore aimed at determining the proximate composition, saponin content, and flavonoid content of jack bean (*Canavalia ensiformis*), velvet bean (*Mucuna sloanei*), black gram (*Vigna mungo*), soybean (*Glycine max*), and faba bean (*Vicia faba*). The findings from this study will provide valuable comparative data on the nutritional and phytochemical profiles of these legumes and contribute to understanding their potential health benefits and suitability for various applications in food and feed systems.

1.1 Justification

Legumes are nutrient-dense and economically important protein sources, yet comparative studies across species remain limited. Jack bean (*Canavalia ensiformis*), velvet bean (*Mucuna sloanei*), black gram (*Vigna mungo*), soybean (*Glycine max*), and faba bean (*Vicia faba*) are notable for their high protein content, adaptability, and resilience to stress, making them valuable for diverse agricultural systems (Foyer *et al*., 2016; Singh *et al*., 2017). The 2023 FAO State of Food Security and Nutrition in the World report highlights persistent global malnutrition, emphasizing the need for nutrient-rich, sustainable crops to improve food security.

While soybean is widely utilized, other legumes like jack bean, velvet bean, black gram, and faba bean remain underutilised despite their nutritional potential. Evaluating their proximate composition, saponin, and flavonoid contents is vital for understanding their dietary and functional value. Saponins contribute to cholesterol reduction and immune support, while flavonoids offer antioxidant and cardiovascular benefits (Sharma *et al*., 2023; Tungmunnithum*et al*., 2018).

With increasing concerns about protein security and sustainable food systems, diversifying legume use is essential. This study provides comparative nutritional and phytochemical data to enhance the utilization of both common and underutilized legumes, supporting global goals for sustainable agriculture, dietary diversity, and improved nutrition.

1.2 Objectives of the Study

To determine and compare the proximate composition, saponin content, and flavonoid content of some selected legumes namely; jack bean (*Canavalia ensiformis*), velvet bean (*Mucuna sloanei*), black gram (*Vigna mungo*), soybean (*Glycine max*), and faba bean (*Vicia faba*) in order to evaluate their nutritional quality and functional potential for human and animal consumption.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction to Legumes

Legumes belong to the family Fabaceae also known as Leguminosae, known for their characteristic pod-bearing seeds. They are cultivated globally for their nutritional, agricultural, and economic value. Notable examples of conventional legumes include beans (*Phaseolus spp),* lentils (*Lens culinaris),* peas (*Pisum sativum)*, chickpeas (*Cicer arietinum)*, peanuts (*Arachis hypogea),* and soybeans*(Glycine max).*Examples of underutilized legumes includes jack bean (*Canavalia ensiformis),* Bambara nut *(vigna subterranea),* and velvet bean *(Mucuna sloanei)* e.t.c. One distinctive feature of legumes is their symbiotic relationship with Rhizobium bacteria in their root nodules, which enables them to fix atmospheric nitrogen thereby enriching soil fertility (Goyal*et al.,* 2021).

Legumes are important sources of plant-based protein, dietary fiber, vitamins (such as folate), and minerals (including iron, calcium, and magnesium). However, they also contain endogenous toxins, anti-nutritional factors (ANFs) substances that can interfere with digestion and nutrient absorption. These include phytates, tannins, trypsin inhibitors, lectins, saponins, oxalates, alkaloids, and cyanogenic glycosides (Maphosa and Jideani, 2017).

Plate 1: Jack bean (*Canavaliaensiformis)*

Plate 2: Bambara nut *(Vignasubterranea)*

Plate 3: Soybeans *(Glycine max)*

Plate 4: Peanut *(Arachis hypogea)*

2.2 Nutritional Composition of Legumes

The nutritional composition of a food refers to the types and amounts of nutrients it contains, which determine its overall dietary value. These nutrients are generally grouped into macronutrients and micronutrients.

Macronutrients include carbohydrates, proteins, and fats which are the primary sources of energy and body-building materials. Carbohydrates supply energy, proteins provide essential amino acids for tissue growth and repair, while fats serve as concentrated energy sources and aid in vitamin absorption (FAO, 2020).

While the m**icronutrients** consist of vitamins and minerals needed in smaller quantities but crucial for body functions such as enzyme activity, immunity, and bone health (WHO, 2021). In addition, water and dietary fiber play vital roles in digestion, metabolism, and overall physiological balance (Wardlaw & Smith, 2021).

The balance and bioavailability of these components vary among foods, influencing their nutritional quality and health benefit (Belitz *et al.*, 2019).

2.2.1 Protein Content and Quality

Protein is one of the most important nutrients in legumes. Most legumes contain between **17% to 25%**protein when measured on a dry weight basis, though soybeans are exceptionally high at 35-40% (Mudryj, Yu, & Aukema, 2014). To put this in perspective, this protein level is much higher than most plant foods and approaches the protein content of meat.

The proteins in legumes are mainly storage proteins, which means they are stored in the seeds to help new plants grow. There are two main types:

- **Globulins** (~70% of total protein): This group comprises legumin and vicilin proteins, which are soluble in salt solutions and rich in amino acids such as arginine and glutamic acid.
- **Albumins** (~25% of total protein): These proteins dissolve in water and present a relatively balanced amino acid profile.

Legume proteins are high in an essential amino acid called **lysine**, but low in sulfur-containing amino acids like **methionine and cysteine**. Essential amino acids are those our bodies cannot produce in sufficient amounts, so we must get them from food. This is why legumes work so well when combined with grains like rice or wheat, which are high in methionine but low in lysine. Traditional meals like beans and rice provide complete protein because they complement each other perfectly (Young & Pellett, 1994).

The Protein Digestibility-Corrected Amino Acid Score (PDCAAS) is a measure used to rate protein quality. For most legumes, this score ranges from 0.5 to 0.7, which is moderate. However, when legumes are eaten with grains, the combined score becomes comparable to animal proteins (Singh, 2017).

2.2.2 Carbohydrate Content and Characteristics

Carbohydrates constitute 50–60% of the dry weight of legumes, predominantly as complex carbohydrates that digest slowly. The principal carbohydrate is **starch** (30–50% of dry weight), notable for its high amylose content (30–40%), which contributes to its slow digestibility, low glycemic index, and increased resistant starch fraction. Resistant starch (5–20% of total starch) is fermented in the colon by beneficial microbiota to produce short-chain fatty acids, particularly butyrate, which nourishes colonocytes and may protect against colorectal cancer (Slavin, 2013).

Legumes are also rich in **dietary fiber** (15–30%), comprising:

- **Soluble fiber**: Forms gels in the digestive tract, aiding in blood glucose regulation and cholesterol reduction (Anderson & Major, 2002).
- **Insoluble fiber**: It adds bulk to stool and improves the gastro intestinal tract, preventing constipation.

Oligosaccharides, such as raffinose, stachyose, and verbascose (3–5% of carbohydrates), are not digested in the small intestine. They are metabolized in the large intestine, promoting the growth of beneficial microbiota such as *Bifidobacteria* and *Lactobacilli*, thus contributing to gut health despite causing flatulence (Guillon & Champ, 2002).

2.2.3 Fat Content and Fatty Acid Profile

Legumes generally have low lipid content (1–3%), except for oilseeds like soybeans and peanuts (Tharanathan & Mahadevamma, 2003). The small lipid fraction is predominantly unsaturated, including polyunsaturated fatty acids (PUFAs) and monounsaturated fatty acids (MUFAs), which provides cardio-protective effects. Legume lipids also contain **tocopherols** (vitamin E) and **phytosterols,** which function as natural antioxidants and cholesterol-lowering agents, respectively.

2.2.4 Mineral Content

Legumes are excellent sources of essential minerals such as iron, zinc, potassium, magnesium, calcium, and selenium. This minerals are important for immune function, maintaining healthy blood pressure, proper nerve function, supporting bone health, muscle function, and antioxidant systems and many enzymatic reactions in the body. Absorption of some minerals, particularly iron and zinc, may be inhibited by phytates and polyphenols; however, co-consumption with vitamin C-rich foods enhances bioavailability.

2.2.5 Vitamin Content

Legumes are especially rich in B-vitamins namely;

Folate (Vitamin B9): Legumes are among the best sources of folate, which is critical for DNA synthesis and preventing birth defects in developing babies.

Thiamine (B1): Important for energy metabolism

Riboflavin (B2): Needed for energy production and cell function

Niacin (B3): Supports digestive system, skin, and nervous system health

Pyridoxine (B6): Essential for protein metabolism and brain development.

They generally contain low levels of fat-soluble vitamins, with vitamin E present in oilseed legumes.

The unique combination of nutrients in legumes provides numerous health benefits, making them important foods for preventing chronic diseases.

2.3 Typical Proximate Composition of Common Legumes

Table 1: Typical Proximate Composition of Common Legumes

Legume	Protein (g)	Carbohydrates (g)	Dietary Fiber (g)	Fat (g)
Soybean	35–40	30–35	9–13	18–20
Lentil	23–26	60–65	10–15	1–2
Chickpea	19–22	60–63	12–17	5–7
Common Bean	20–24	60–65	15–20	1–2
Peas	22–25	58–62	14–18	1–2

Sources: Messina (1999); Mudryj et al. (2014); Singh (2017); Tharanathan & Mahadevamma (2003); Rebello et al. (2014)

2.4 Nutritional importance of Legume Consumption

Regular legume consumption provides multiple health benefits, owing to their combined nutrient and phytochemical profiles.

Cardiovascular Health: Many studies have shown that eating legumes regularly helps protect the heart and blood vessels.The soluble fiber in legumes contribute to improved lipid profiles by binding with bile acids in the intestines forcing the body to use cholesterol from the blood to produce new bile acids. This process reduces total cholesterol and LDL cholesterol levels, thereby preventing cardiovascular disease risk (Bazzano *et al.*, 2001).

Additionally, the high potassium and low sodium content in legumes helps maintain healthy blood pressure.

Diabetes Management: The high amylose starch and viscous soluble fiber in legumes causes glucose to be released slowly and steadily into the bloodstream, rather than causing sudden spikes in blood sugar. Research has shown that diets rich in low-glycemic index foods like legumes improve long-term blood sugar control suitable for diabetic and pre-diabetic populations (Jenkins *et al.*, 2012).

Digestive and Gut Health: The high fiber content in legumes plays a crucial role in maintaining digestive health. The resistant starch and soluble fiber that reach the colon serve as food for beneficial bacteria. These bacteria ferment the fiber to produce short-chain fatty acids, particularly butyrate, which:

- Provides energy for the cells lining the colon
- Reduces inflammation in the gut
- May help prevent colorectal cancer (Slavin, 2013)

The insoluble fiber adds bulk to stool and promotes regular bowel movements, preventing constipation and conditions like diverticulosis.

Weight Management: High protein and fiber content increases satiety, supporting caloric control and weight management (Rebello, Greenway, & Finley, 2014).

Environmental Sustainability: Legume cultivation improves soil nitrogen content through their relationship with rhizobium, reduces synthetic fertilizer dependence, and contributes to sustainable agricultural systems (Foyer *et al*., 2016).

2.5 Phytochemicals in Legumes

Phytochemicals are a diverse group of naturally occurring plant metabolites that, while not classified as essential nutrients, play important physiological roles in humans. Legume seeds accumulate a broad spectrum of these compounds which can influence digestion, mineral availability and metabolic processes. At elevated concentrations, certain phytochemicals act as anti-nutritional factors by binding proteins or chelating minerals, thereby reducing nutrient absorption. However, thermal processing, soaking, fermentation and other common household treatments typically lower their inhibitory effects and, in many cases, enhance the bio-accessibility of beneficial components. As a result, properly prepared legumes often provide phytochemicals at levels associated with antioxidant, anti-inflammatory and metabolic health benefits (Sharma & Giri, 2022).

2.5.1 Anti-Nutritional Factors (ANFs)

Compounds such as saponins, tannins and protease inhibitors can impair nutrient utilization when present in high amounts. Yet traditional processing steps including soaking, heating, sprouting and fermenting tend to lower the concentrations of these anti-nutritional factors while maintaining, and in some cases improving, the functional and health-promoting qualities of legumes (Sharma & Giri, 2022).

2.5.2 Saponins in Legumes

Saponins are diverse group of compounds found throughout the plant kingdom, with legumes being particularly rich sources. Chemically, saponins are glycosides, consisting of a sugar molecule attached to a non-sugar molecule. The name "saponin" comes from the Latin word "sapo" meaning soap, because these compounds create foam when shaken with water, similar to soap (Shi, Arunasalam, & Yeung, 2004).

They are classified into two main types based on their structure:

Legumes are rich in triterpenoid saponins, which have a 30-carbon backbone, while steroidal saponin compounds structurally similar to cholesterol occur in smaller amounts. These molecules are often labeled as anti-nutritional because they can bind to important nutrients and components of the digestive system, potentially reducing the absorption of minerals such as iron and zinc. Saponins can also interact with intestinal cell membranes, slightly increasing permeability, and they may attach to cholesterol and dietary proteins during digestion, influencing how fats and proteins are metabolized. Additionally, they contribute a naturally bitter or astringent taste to some legumes, which can affect food acceptability (Multescu et al., 2024).

Although saponins can be toxic at very high concentrations, the levels present in properly cooked legumes are generally safe and may even offer health benefits. Research has shown that saponins at dietary levels can have several positive effects on human health. For instance, they can help lower blood cholesterol by binding to cholesterol and bile acids in the intestines, preventing their absorption. This process forces the liver to use more circulating cholesterol to produce new bile acids, resulting in reduced total cholesterol and LDL cholesterol levels (Shi et al., 2004). Saponins have also been reported to enhance immune function, which is why they are sometimes used as adjuvants in vaccines to boost the body’s immune response.

Furthermore, laboratory studies suggest that saponins possess anti-cancer properties, including the ability to induce apoptosis in cancer cells, inhibit tumor growth, and prevent cancer cell metastasis, though more research in humans is needed to confirm these effects (Zhu et al., 2018). Saponins also exhibit anti-inflammatory activity, which may help reduce the risk of chronic diseases associated with persistent inflammation.

Various methods exist for measuring saponin content in legumes. Spectrophotometric techniques, such as the vanillin-sulfuric acid assay, involve a chemical reaction that produces a colored compound measurable with a spectrophotometer. Chromatographic approaches, including High-Performance Liquid Chromatography coupled with Mass Spectrometry (HPLC-MS), allow for the precise identification and quantification of individual saponin molecules, providing a detailed profile of these bioactive compounds (Kumar et al., 2021).

2.5.3 Flavonoids in Legumes

Flavonoids are polyphenolic compounds abundantly found in legumes, contributing not only to the coloration of seeds, flowers, and pods but also to their nutritional and medicinal properties (He & Giusti, 2010; Awika & Rooney, 2004). The concentration and composition of flavonoids in legumes are influenced by the plant's genotype, environmental conditions, developmental maturity, and processing methods, all of which can alter their bioavailability (Messina, 2016).

Quantification of flavonoids is commonly achieved through spectrophotometric methods, such as the aluminum chloride assay, or by high-performance liquid chromatography (HPLC) for the detection of individual flavonoid compounds (Awika & Rooney, 2004). Among the major classes present in legumes, anthocyanins found in black beans, red kidney beans, and purple lentils impart red, purple, and blue pigmentation and are associated with antioxidant, cardio-protective effects, and potential enhancements in visual function and memory (He &

Giusti, 2010). Flavonols such as quercetin and kaempferol are predominant in lentils, chickpeas, and green beans, and exhibit neuroprotective and anti- inflammatory properties (Awika & Rooney, 2004). Isoflavones, mainly present in soybeans, act as phytoestrogens with possible benefits for menopausal symptoms, bone health, and cardiovascular function (Messina, 2016). Catechins and proanthocyanidins, which are also found in various legumes, contribute further antioxidant, antimicrobial, and anti-carcinogenic effects (Awika & Rooney, 2004).

Processing methods can significantly influence flavonoid content. Soaking legumes may result in leaching of flavonoids into the soaking water, while cooking can have dual effects: it may increase bioavailability by breaking down cell walls, but also decrease overall content as a result of heat- induced degradation (Messina, 2016). Because the water used during soaking or cooking may retain appreciable amounts of flavonoids, incorporating this water into recipes can be a practical strategy to preserve these beneficial compounds (He & Giusti, 2010).

2.5.4Other Important phytochemicals in legumes

Phytic Acid (Phytate): is the primary storage form of phosphorus in legume seeds. It strongly binds to minerals like iron, zinc, calcium, and magnesium thereby reducing the bioavailability of these minerals for absorption. However, phytic acid also acts as an antioxidant, has anti-cancer potential and helps regulate blood sugar (Gupta, Gangoliya, & Singh, 2015).

Protease inhibitors: These are proteins that inhibit digestive enzymes (proteases) like trypsin and chymotrypsin, reducing protein digestion. The most studied is the Bowman-Birk Inhibitor (BBI) found in soybeans and other legumes. They are studied for their chemo-preventive properties and immunomodulatory effect (Clemente & Sonnante, 2020).

Lectins: They are proteins that bind to specific carbohydrates. Some lectins, like phytohaemagglutinin in raw kidney beans, can be toxic and cause severe digestive upset. However, thorough cooking destroys harmful lectins. Some purified lectins show potential anti-cancer properties and may have roles in immune function.

Phytosterols: They are plant compounds structurally similar to cholesterol found in the fat fraction of legumes, particularly in oilseeds. They compete with dietary cholesterol for absorption in the intestines, help lower blood cholesterol levels.

Phenolic acids: These simple phenolic compounds are found in the seed coat of legumes, they include ferulic acid, caffeic acid, and others. They have antioxidant properties, may contribute to disease prevention

2.6 Effects of Processing on Phytochemicals

Processing methods such as soaking, boiling, germination, and fermentation effectively reduce anti-nutritional factors while retaining or enhancing bioactive compounds, improving digestibility, and nutrient bioavailability.

2.6 Factors Influencing Phytochemical Content

Phytochemical levels in legumes are affected by several factors, including the type of legume, growing conditions, harvest time, storage conditions. Different species and varieties naturally have different amounts and types of phytochemicals. For example, black beans usually have more anthocyanins than white beans, soybeans are high in isoflavones, and some lentil varieties have been bred to have more flavonoids (Alghamdi et al., 2017; Frontiers in Plant Science, 2016).

The environment where the legumes grow also matters. Sunlight, especially UV light, can increase flavonoid production. Soil quality, water availability, and temperature can also affect how the plant makes these compounds (Managing phenol contents in crop plants, 2011). Moderate water stress may even increase some phytochemicals as part of the plant's natural defense.

The stage of maturity at harvest also affects phytochemical content. Fully mature, dry legumes generally have more storage compounds and phytochemicals than immature seeds. For example, in mung beans, certain flavonoids remain stable, but overall antioxidant activity varies depending on the seed and variety (Foods, 2024).

Legume storage after harvest can also change their phytochemical levels. Long storage can cause some compounds to break down, but keeping legumes cool, dry, and away from light helps preserve them. Some processing, such as roasting, may reduce certain phytochemicals but leave others unchanged (Food Chemistry, 2023).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 SOURCES OF MATERIALS

The legume samples were obtained from the Food Science and Nutrition Department Food Bank, University of Benin, Benin City, Nigeria. The seeds were cleaned to remove stones, broken seeds, and other foreign materials. Clean and undamaged seeds were selected, labeled properly, and stored in airtight containers at room temperature until required for analysis.

3.2 SAMPLE PREPARATION

Seeds were kept in the oven set at 60°C. The roasting duration was determined by the ease of removal of testa and brownness of cotyledon. Roasted beans were milled with a mortar and pestle, stored and labeled until used for proximate and phytochemical analysis.

Plate 5: sample preparation

3.3 WENDE OR PROXIMATE ANALYSIS

The proximate composition of the legume samples was determined following the procedures of the **Association of Official Analytical Chemists (AOAC, 2019).** The parameters analyzed included**moisture, ash, crude protein, crude fat, crude fiber, and nitrogen free extract**. Proximate analysis of experimental materials was carried out in the Central Laboratory, Faculty of Agriculture, University of Benin, Benin-City, Edo state, with little modificationby Isikhuemen and Efenudu *et al* (2020).

3.3.1 APPARATUS AND EQUIPMENT

Analytical weighing balance, laboratory blender, 60-mesh sieve, Soxhlet extractor, Kjeldahl digestion and distillation unit, muffle furnace, centrifuge, water bath, UV–Visible spectrophotometer, standard glassware, Whattman filter paper, Calibration curve, mortar and pestle.

3.3.2 DRY MATTER AND MOISTURE DETERMINATION

Moisture is determined by the loss in weight that occurs when a sample is dried to a constant weight in an oven. About 1g of each legume sample is weighed into separate crucibles previously dried and weighed. Each sample is then dried in an oven for 103°C for about 36hours, cooled in a desiccator and weighed. The drying and weighing is repeated until a constant weight is achieved.

$Moisture\ (\%) = \frac{W1-W2}{W1-W0} \times 100$

Where;

(W_0) = weight of crucible

(W_1) = weight of crucible + sample before drying

(W_2) = weight of crucible + sample after drying

$$\%\ Dry\ matter\ (DM)\ =\ 100\ -\ \%Moisture$$

3.3.3 ASH DETERMINATION

Ash is the inorganic residue obtained by burning off the organic matter of a sample at 550to 600°C in Muffle furnace for 6 hours. 1g of each sample is weighed into a pre-heated crucible. The crucible is placed into the Muffle furnace at 550-600°C for 6 hours or until whitish-grey ash is obtained. The crucible is then placed in the desiccator and weighed.

The ash content is expressed as;

$$Weight\ of\ ash \div weight\ of\ Sample \times 100$$

3.3.4ETHER EXTRACT DETERMINATION

The ether extract represents the fat and oil present in the legume sample. Soxhlet apparatus is the equipment used for the determination of ether extract. It consist of 3 major components: an extractor, comprising the thimble which holds the sample; condenser for cooling and condensing the ether vapor and a 250ml flask.

Procedure: About 200ml petroleum ether of boiling point of 40-60°C is placed in the flask. 1g of homogenized sample is weighed into a thimble and the thimble is plugged with cotton wool. The thimble with content is placed into the extractor. The ether in the flask is then heated. As the ether vapor reaches the condenser through the side arm of the extractor, it condenses to liquid form and drop back into the sample in the thimble. The ether soluble substances are dissolved and are carried into solution through the siphon tube back into the flask. The extraction continues for at least 4 hours. The thimble is removed and most of the solvent is distilled from the flask into the extractor. The flask is then disconnected and placed in an oven at 75°C for 1hour30mins then cooled in a desiccator and weighed.

$$\%Ether\ extract = \ weight\ of\ fat \div weight\ of\ sample\ \times 100/1$$

3.3.5 CRUDE FIBRE DETERMINATION

The organic residue left after extraction of legume sample with ether can be used to determine the crude fiber. However, if a fresh sample is used, the fat in it could be extracted by adding petroleum ether, stir, allow it to settle and decant. Do this three times. The fat-free material is then transferred into a flask or beaker. 200ml of pre-heated 1.25% H_2SO_4 is added and the solution is gently boiled for about 30 minutes, maintaining constant volume of acid by the addition of hot water. The Buckner flask funnel fitted with filter is pre-heated by pouring hot water into the funnel. The boiled acid sample mixture is then filtered hot through the funnel under sufficient suction. The residue is then washed several times with boiling water (until the residue is neutral to litmus paper) and transferred back into the beaker. Then 200ml of pre-heated 1.25% Na_2SO_4 is added and boiled for another 30 minutes. Filter under suction and washed thoroughly with hot water and twice with ethanol. The residue is dried at 100°C until a constant weight is known. It is then transferred into a crucible and placed in Muffle furnace (500-600°C) and ashed, then cooled in a desiccator and weighed.

$$\%Crude\ fiber\ = weight\ of\ crude\ fiber \div weight\ of\ original\ sampled \times 100/1$$

3.3.6 CRUDE PROTEIN DETERMINATION

Crude protein is determined by measuring the nitrogen content of the sample and multiplying it by a factor of 6.25. This factor is based on the fact that most protein contains 16% nitrogen. Crude protein is determined using the Kjeldahl procedure. This procedure has 3 main universal stages namely: Digestion, Distillation and Titration.

Digestion: Weigh about 1g of the homogenized sample into a Kjedahl flask, add 10 ml of concentrated sulphuric acid and add kjedahl catalyst. Apply heat to the sample slowly at first then consistent, continue to digest for 45 minutes until the digesta become clear pale green. Leave until completely cool and rapidly add up to 100ml of distilled water. Rinse the digestion flask 2-3 times and add the rinsing to the bulk to get the aliquot.

Plate 6: Digestion process

Distillation: Steam up the distillation apparatus and add about 5ml of the digest into the apparatus via a funnel and allow it to boil. Add 5ml of sodium hydroxide and 50ml of water from the measuring cylinder so that ammonia is not lost. Distil into 5ml of 2% boric acid containing screened methyl red indicator.

Plate 7: Distillation process

Titration: The alkaline ammonium borate formed is titrated directly with 0.1N HCl. The titre value which is the volume of acid used is recorded. The volume of acid used is fitted into the formula which becomes:

%CP= NA × 14/1000 ×volume of acid ×100/volume of digest used ×100/weight of sample

% Crude protein = %N x 6.25

3.3.7 NITROGEN FREE EXTRACT (NFE)

NFE is determined by mathematical calculation. It is obtained by subtracting the sum of percentages of all the nutrients already determined on dry matter basis from 100.

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

NFE represents soluble carbohydrates and other digestible and easily utilizable non-nitrogenous substances in the sample.

3.4 ANALYSIS OF PHYTOCHEMICAL CONTENTS

SAMPLE PREPARATION

1.0g of the sample was weighed and dissolved in 50ml of cool boiled-out distilled water in a 100ml beaker. This was transferred to a 100ml standard flask. The beaker was rinsed into the standard flask three times with about 10ml of the boiled out distilled water. It was then made up to mark with the same distilled. The flask was corked and inverted four times for proper mixing and then set aside for analysis. This solution has a concentration of 10000µg/ml.

3.4.1 DETERMINATION OF TOTAL PHENOLIC CONTENTS

The amount of total phenols in the extract was determined with Folin–Ciocalteu reagent according to standard protocols as reviewed by Raposo, Borja & Gutiérrez- González (2024), with slight modification using tannic acid as a standard.

Briefly, 1.0ml of extract solution (250µg/ml) was added in a test tube. Then, 1.0 mL of Folin–Ciocalteu reagent was added, and the contents of the flask were mixed thoroughly. After 5 min, 15.0 ml Na2CO3 (20 %) was added and allowed to stand for 2 hours. The absorbance was measured at 760 nm using a UV-Vis spectrophotometer (Jenway 6100, Dunmow, Essex, U.K). The total phenolic content was determined as µg of tannic acid equivalent(TAE) using an equation obtained from the standard tannic acid calibration graph.

3.4.2 FLAVONOID CONTENT DETERMINATION

The flavonoid content was determined on triplicate aliquots of the homogenous cabbage extract (1.5 g) (Ilahy *et al*., 2011). Thirty-microliter aliquots of the methanolic extract were used for flavonoid determination. Samples were diluted with 90µl methanol, 6µl of 10% Aluminum chloride ($AlCl_3$), 6µl of 1mol/l Sodium acetate (CH_3CO_2Na) were added and finally 170µL of methanol was added. The absorbance was read at 415 nm after 30 min. Quercetin was used as a standard for calculating the flavonoid content (mg Qe/kg).

3.4.3 ESTIMATION OF TOTAL SAPONINS CONTENT

The estimation of total saponins content was determined by the method described by Makkar et al. (1993).

Based on vanillin-sulphuric acid colorimetric reaction with some modifications. About 50 µL of plant extract was added with 250 µL of distilled water. To this, about 250 µL of vanillin reagent (800mg of vanillin in 10Ml of 99.5% ethanol) was added. Then 2.5mLof 72%sulphuric acid was added and it was mixed well. This solution was kept in a water bath at 60°Cfor 10min. After 10min, it was cooled in ice cold water and the absorbance was read at 570nm. 0- 25 ppm standard saponin solutions were prepared from saponin stock solution. The standard solutions were treated similarly as test samples. The values were expressed as mg/kg.

3.4.4 ESTIMATION OF TANNINS CONTENT

Exactly 0.20 mL of sample was added to 20 mL of 50% methanol and placed in a water bath at 77˚C - 80˚C for 1hr and shaken. The extract was quantitatively filtered using a double layered Whatman No.1 filter paper and 20 mL of distilled water, 2.5 mL Folin-Denis reagent and 10 mL 17% Na_2CO_3 were added and mixed. The mixture was allowed to stand for 20 min. A series of standard tannic acids solutions were prepared in methanol and their absorbance as well as samples was read after color development on a UV/ Visible spectrophotometer at a wavelength of 760 nm. Total tannin content was calculated from calibration curve.

3.4.5 PHYTATE DETERMINATION

4g of the samples was taken and soaked in 100 ml of 2% HCL for 3 hours; it was then filtered through Whatman filter paper. 25 ml of the filtrate was placed in a 250 ml conical flask, followed by the addition of 5 ml of 0.3% Ammonium thiocyanate solution as an indicator. 53.5 ml of the distilled water was added to give the desired acidity. This was then titrated with standard iron (III) chloride solution, which contains about 0.00195g of iron per ml, until a brownish yellow persists for 5 minutes.

% Phytic Acid = 8.24t ×100/1000 × weight of sample.

Where: t = titre value

3.4.6OXALATE DETERMINATION

About 1g of the sample was added to 75 ml of 1.5N H_2SO_4, and the solution was carefully stirred using a magnetic stirrer for 1 hour before being filtered using Whatman No. II filter paper. 25 ml of the extract was collected and titrated when hot against 0.1N $KMnO_4$ solution to a faint pink color endpoint.

Oxalate = (titre value × 0.9004) mg/g

3.5 Statistical Analysis: All analyses for proximate composition, saponin, and flavonoid content of the legume samples were conducted in triplicates. Data obtained from the experiments were subjected to Analysis of Variance (ANOVA) using **GENSTAT 12th Edition** to determine differences among the legume samples. Significant differences between treatment means were separated using **Duncan's Multiple Range Test (DMRT)**at a**5% probability level ($p < 0.05$)**. Results were expressed as mean ± standard deviation.

CHAPTER FOUR

4.0 RESULTS

4.1 PROXIMATE COMPOSITION OF SOME LEGUMES

The proximate composition of some legumes are presented in Table 2.

Table 2: Proximate Composition of some Legume seed flour

SAMPLE	MC%	CP%	EE%	CF%	ASH%	NFE%
SB	3.61	42.0	15.68	5.75	3.03	29.93
FB	5.87	25.74	8.96	9.00	4.53	45.90
BG	4.79	20.00	6.10	5.47	1.60	62.04
JB	5.82	17.33	9.71	10.00	1.92	55.22
VB	1.30	25.74	5.65	4.69	3.79	58.83

Note: SB= Soybean, FB= Faba bean, BG= Black gram, JB=Jack bean, VB=Velvet bean.

This table compares the basic nutritional composition of five different types of beans. The values are percentages (%), meaning that for every 100 grams of dry bean, this is the breakdown of its content.

MC% (Moisture Content):

The represents amount of water present in the sample. Lower moisture is generally better for storage, as it prevents microbial growth and spoilage. All samples have relatively low moisture, with Velvet Bean (VB) being the driest (1.30%) and Faba Bean (FB) having the highest (5.87%).

CP% (Crude Protein):

This estimates the total protein content. Soybean (SB) has the highest protein content (42.0%), making it an exceptional source. The others, especially Black Gram (20.00%), Jack Bean (17.33%), and Velvet Bean (25.74%), have significantly lower protein content.

EE% (Ether Extract / Crude Fat): This estimates the total fat or lipid content present in the sample. Faba Bean (FB) and Jack Bean (JB) have the highest fat content (9-10%), which contributes to their energy density. Soybean (SB) has a moderate amount (15.68%), while Velvet Bean (VB) is very low (5.65%).

CF% (Crude Fiber):

This measures the indigestible cellulose, lignin, and other fibrous components. It gives a rough estimate of dietary fiber. Jack Bean (JB) has the highest fiber content (10.00%), followed by Faba Bean (FB) at 9.00%. High fiber is good for digestive health but can lower the overall digestibility of the feed for monogastric animals (like poultry and pigs).

ASH% (Ash Content):

This represents the total mineral content, the inorganic residue left after the sample is completely burned. Faba Bean (FB) has the highest ash content (4.53%), suggesting a richer mineral profile. Black Gram (1.60%) and Jack Bean (1.92%) have the lowest.

NFE% (Nitrogen-Free Extract):

This is not measured directly but calculated. It represents the easily digestible carbohydrates, primarily starches and sugars.

Calculation: `NFE% = 100% - (MC% + CP% + EE% + CF% + Ash%)`

This is the main energy source in most feeds. Black Gram (BG) has the highest NFE (62.04%), meaning it is predominantly starchy. Soybean (SB) has the lowest (29.93%) because its composition is dominated by protein and fat instead.

4.2 PHYTOCHEMICAL CONTENT OF SOME LEGUMES

The levels of phytochemical content in some selected legumes are represented in Table 3.

Table 3: Quantitative Phytochemical Content of Some Legumes (g/1000g DM seed flour)

Samples	PHENOLS	FLAVONOIDS	TANINS	SAPONINS	OXALATE	PHYTATE	SEM
JB	163.4^{a}	111.5^{a}	22.4^{d}	4.8^{b}	248.7^{c}	2593.3^{a}	32.3
FB	87.5^{d}	56.3^{c}	32.7^{b}	3.5^{c}	13.1^{d}	465.2^{c}	10.6
WB	97.1^{c}	57.0^{c}	21.6^{d}	4.6^{b}	340.1^{b}	1808.0^{b}	3.4
SB	150.1^{b}	84.8^{b}	50.5^{a}	5.6^{a}	1791.1^{a}	225.1^{d}	2.4
VB	55.9^{e}	15.0^{d}	27.2^{c}	5.7^{a}	3.8^{e}	91.2^{e}	1.3

Note: JB=Jack bean, FB= Faba bean, WB=White bean, SB=Soybean, VB=Velvet bean. The unit of measures for the phytochemicals are; Total phenolic content (g TAE/kg), Flavonoid content (g QE/kg), Total Tannins content (g TAE/kg), Saponin (g/kg), 5=Oxalate (mg/100mg), Phytate (mg/100mg). Mean values followed by different superscript letters within the same column are significantly different at 5% probability level according to Duncan's Multiple Range Test. SEM = Standard Error of Mean.

The table presents the phytochemical contents in some selected legumes, showing their levels of concentration in the selected legumes. Here’s an explanation of each phytochemical parameter:

1. TOTAL PHENOLIC CONTENT (g TAE/kg): Jack Bean has the highest phenolic content (163.4 g TAE/kg), while Velvet Bean (55.89 g TAE/kg) has the lowest. Soybean demonstrated high levels (150.1 g TAE/kg), comparable to Jack Bean. White Bean and Faba Bean shows moderate levels (97.1 and 87.5 g TAE/kg respectively). Phenolic compounds are known to provide antioxidant protection against oxidative stress, reduce inflammation, and help prevent chronic diseases including cardiovascular disease and cancer. It may also contribute to bitter taste when found in high concentrations. Jack Bean and Soybean show superior functional food potential due to high phenolic content.

2. FLAVONOID CONTENT (g QE/kg): Jack Bean contains the highest flavonoid levels (111.5 g QE/kg), higher than Velvet Bean (15.04 g QE/kg), which has the lowest content. Soybean shows moderately high levels (84.8 g QE/kg). Faba Bean and White Bean are similar and moderate (56.3 and 57.0 g QE/kg). Flavonoids offer cardiovascular protection, anti-cancer properties, anti-inflammatory effects, and immune support. Jack Bean's high content makes it valuable for disease prevention applications.

3. TOTAL TANNIN CONTENT (g TAE/kg): Soybean has the highest tannin content (50.5 g TAE/kg), while White Bean showed the lowest (21.6 g TAE/kg). Jack Bean also has similarly low levels (22.4 g TAE/kg). Faba Bean and Velvet Bean showed moderate levels (32.7 and 27.17 g TAE/kg). Tannins are known to reduce protein digestibility and mineral absorption but also provide antioxidant and antimicrobial benefits. The relatively low levels across all legumes (21.6-50.5 g TAE/kg) indicate good palatability with minimal processing needs.

4. SAPONIN CONTENT (g/kg): Velvet Bean and Soybean shows the highest saponin content (5.67 and 5.6 g/kg), while Faba Bean has the lowest (3.5 g/kg). Jack Bean and White Bean were intermediate (4.8 and 4.6 g/kg). All values were remarkably low and similar across legumes. Saponins lower cholesterol, exhibit anti-cancer properties, and regulate blood sugar. The uniformly low levels (3.5-5.67 g/kg) indicate excellent palatability and minimal processing requirements while maintaining health benefits.

5. OXALATE CONTENT (mg/100g): Soybean exhibited extraordinarily high oxalate content (1791.1 mg/100g), while Velvet Bean (3.79 mg/100g) shows the lowest levels. White Bean also showed high content (340.1 mg/100g). Jack Bean was moderate (248.7 mg/100g), while Faba Bean was low (13.1 mg/100g).Oxalates bind calcium and minerals, reducing bioavailability and increasing kidney stone risk. Soybean's exceptionally high content contraindicates use for kidney stone-prone individuals. Velvet Bean and Faba Bean are safer options. Processing through soaking and boiling reduces oxalates by 40-70%.

6. PHYTATE CONTENT (mg/100g): Jack Bean contained exceptionally high phytate levels (2593.3 mg/100g), than Velvet Bean (91.16 mg/100g), which had the lowest content. White Bean also shows very high levels (1808.0 mg/100g). Faba Bean was moderately high (465.2 mg/100g), while Soybean was moderate (225.1 mg/100g). Phytates bind iron, zinc, calcium, and magnesium, reducing bioavailability by 50-80%, potentially causing deficiencies. However, they also provide antioxidant and anti-cancer benefits. High-phytate legumes (Jack Bean, White Bean) require fermentation or sprouting (reduces phytates 50-75%) and should be consumed with vitamin C-rich foods.

CHAPTER FIVE

5.0 DISCUSSION

5.1 PROXIMATE COMPOSITION OF SOME LEGUMES

The proximate composition of legumes provides important insight into their nutritional potential and possible applications in human and animal nutrition. The present study compared the basic nutritional composition of **soybean (SB)** with other less-utilized legumes **faba bean (FB)**, **black gram (BG)**, **jack bean (JB)**, and **velvet bean (VB)** based on their moisture, crude protein, ether extract, crude fiber, ash, and nitrogen-free extract (NFE) contents.

Moisture Content

The moisture content of the legume samples ranged from (1.30% in velvet bean to 5.87%) in faba bean. These values are within the safe range for dry legumes (below 10%), indicating good storage stability and reduced risk of microbial spoilage (Adeyeye, 2016). The relatively low moisture of velvet bean suggests longer shelf life and lower susceptibility to fungal attack during storage. Conversely, the slightly higher moisture in faba bean may require more careful drying before long-term storage. Soybean had a moderate moisture content of (3.61%,) consistent with values reported by(Olanrewaju *et al*. (2020) for dried soybeans.

Crude Protein

Protein content varied widely among the samples, with soybean exhibiting the highest crude protein value (42.00%), followed by velvet bean (25.74%) and faba bean (25.74%). Black gram (20.00%) and jack bean (17.33%) contained lower protein levels. The high protein content of soybean confirms its well-established reputation as a major plant protein source used both in human diets and animal feed (Kumar *et al*., 2021). However, the moderate protein levels in the underutilized legumes especially velvet bean and faba bean demonstrate that these species could serve as alternative protein sources, particularly in regions where soybean production is limited or expensive. Similar findings were reported by Ezeagu and Ibegbulem (2020), who noted that velvet bean and jack bean contain adequate protein levels suitable for feed formulation after detoxification.

Ether Extract (Crude Fat)

The ether extract values ranged from (5.65%) in velvet bean to (15.68%) in soybean. Soybean’s high fat content distinguishes it from most legumes and contributes to its high energy value and importance as a source of vegetable oil (Abebe *et al*., 2018). In contrast, the relatively low fat content of faba bean, black gram, and velvet bean suggests they are better suited for carbohydrate- or protein-based applications rather than oil extraction. Jack bean (9.71%) and faba bean (8.96%) showed moderate lipid levels, which could improve palatability and energy density in feed formulations. The observed differences in fat content reflect genetic variation and environmental factors affecting lipid biosynthesis in legumes (Olanrewaju *et al*., 2020).

Crude Fiber

Crude fiber values ranged between 4.69% and 10.00%, with jack bean having the highest (10.00%) and velvet bean the lowest (4.69%). High fiber content, as seen in jack bean and faba bean, can aid digestion in ruminant diets but may reduce nutrient digestibility for monogastric animals (Akinjayeju, 2019). Soybean’s moderate fiber level (5.75%) enhances its versatility in feed and food applications. The variation among samples could be attributed to differences in seed coat composition and maturity stage during harvest (Ezeagu and Ibegbulem, 2020).

Ash Content

Ash content indicates the total mineral composition of the legumes. Faba bean recorded the highest ash value (4.53%), suggesting a rich mineral profile, while black gram and jack bean had the lowest (1.60% and 1.92%, respectively). Soybean's ash value (3.03%) is within the typical range for legumes (2–5%) as reported by Adeyeye (2016). The mineral content of legumes is influenced by soil fertility and genotype. Faba bean's higher ash content may be beneficial nutritionally but also indicates potential for higher mineral anti-nutrients such as phytates and oxalates if not properly processed (Kumar *et al.,* 2021).

Nitrogen-Free Extract (NFE)

NFE represents the carbohydrate fraction of the legumes and ranged from (29.93%) in soybean to 62.04% in black gram. The high NFE in black gram indicates it is predominantly starchy and could serve as an important energy source. In contrast, the low NFE of soybean reflects its inverse relationship with protein and lipid content—its energy is derived largely from fat rather than carbohydrate. Velvet bean (58.83%) and jack bean (55.22%) also had high NFE values, suggesting substantial carbohydrate availability, though the presence of anti-nutritional factors such as trypsin inhibitors may limit digestibility (Ezeagu and Ibegbulem, 2020; Abebe *et al.,* 2018).

5.2 PHYTOCHEMICAL COMPOSITION OF SOME LEGUME

Flavonoid content of some selected legume

Flavonoids are naturally occurring polyphenolic compounds that play vital roles in protecting the body against oxidative stress and inflammation. From the results presented, Jack bean (111.5 g QE/kg) exhibited the highest flavonoid content, surpassing Soybean (84.8 g QE/kg), while Velvet bean (15.0 g QE/kg) recorded the lowest. Faba bean (56.3 g QE/kg) and White bean (57.0 g QE/kg) showed moderate levels of flavonoids.

The high flavonoid content of Jack bean indicates strong antioxidant potential, suggesting that this underutilized legume could offer greater health-promoting benefits than Soybean. Flavonoids are known to scavenge free radicals, enhance immune function, and reduce the risk of cardiovascular diseases, diabetes, and certain cancers (Okwu and Emenike, 2020; Harborne, 1998). This implies that Jack bean could serve as a valuable ingredient in functional foods designed to combat oxidative stress-related diseases.

In contrast, Velvet bean's low flavonoid content suggests it may offer less antioxidant protection compared to Soybean or Jack bean. However, moderate levels observed in Faba bean and White bean indicate that these legumes still contribute appreciably to dietary antioxidant intake. Compared with Soybean a widely recognized source of bioactive compounds both Jack bean and Faba bean demonstrate promising flavonoid concentrations that could make them suitable alternatives for enhancing the antioxidant quality of human diets.

Overall, the variation in flavonoid levels among the legumes may be attributed to genetic differences, seed coat pigmentation, and environmental factors affecting secondary metabolite synthesis (Duenas *et al*., 2015). From a nutritional perspective, Jack bean's superior flavonoid concentration positions it as an excellent candidate for food fortification, nutraceutical production, and the development of antioxidant-rich dietary supplements.

Saponin Content of Some Selected Legumes

Saponins are glycosidic compounds known for their diverse physiological effects, including cholesterol-lowering, antimicrobial, anti-inflammatory, and anti-cancer properties. However, at excessive levels, they can impart bitterness and cause hemolysis of red blood cells, though such effects are typically minimized through processing (Price *et al*., 1987; Yoshiki *et al*., 2021).

The data revealed that Velvet bean (5.7 g/kg) and Soybean (5.6 g/kg) recorded the highest saponin contents, while Faba bean (3.5 g/kg) showed the lowestJack bean (4.8 g/kg) and White bean (4.6 g/kg) exhibited intermediate values. These results indicate that the saponin concentrations in all the legumes are within a relatively narrow range (3.5–5.7 g/kg), suggesting minimal variation among species.

The comparable saponin contents of Velvet bean and Soybean imply that Velvet bean could perform similar physiological functions in the body, especially in lowering serum cholesterol and supporting cardiovascular health (Shi *et al*., 2004). This finding enhances the nutritional and functional importance of Velvet bean as an underutilized legume with potential for food and nutraceutical applications.

Although Faba bean showed the lowest saponin content, it remains nutritionally valuable since excessive saponin consumption can affect taste and digestibility. Jack bean and White bean, with moderate saponin levels, balance functionality and palatability, providing health benefits without undesirable bitterness. Processing methods such as boiling, soaking, or fermentation can further reduce saponin levels while retaining their beneficial properties (Esenwah and Ikenebomeh, 2008).

In comparison with Soybean the most widely used conventional legume Velvet bean and Jack bean demonstrate comparable or only slightly lower saponin levels, indicating that they can be viable substitutes in functional foods aimed at promoting heart health, managing cholesterol levels, and reducing cancer risk.

These results suggests that underutilized legumes can effectively complement or substitute Soybean in human diets and food industries. Their exploitation could help reduce reliance on Soybean, promote biodiversity, and support food security by encouraging the use of locally available but neglected legume species.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

This research confirms that legumes represent highly valuable plant protein sources with diverse nutritional and functional profiles. Soybean remained the most nutrient-dense, characterized by its superior protein and fat levels. However, the study also established that other lesser-known legumes such as velvet bean, faba bean, black gram, and jack bean possess considerable potential for food and feed purposes. Black gram's high carbohydrate content identifies it as an excellent energy source, while velvet bean and faba bean demonstrated sufficient protein and mineral levels suitable for dietary inclusion.

The generally low moisture contents across all samples indicate good storage potential, while fiber variation highlights their adaptability to both monogastric and ruminant feeding systems following proper processing. The presence of flavonoids and saponins across species suggests additional health benefits, including antioxidant, anti-inflammatory, and immune-supportive effects.

Although soybean remains the dominant legume in global nutrition, this study shows that promoting the cultivation and utilization of underused species especially jack bean and velvet bean could reduce reliance on soybean imports, improve dietary variety, and foster local agricultural development. Integrating these legumes into production and consumption systems would contribute to both nutritional well-being and sustainable food supply chains.

6.2 **Recommendations**

- Traditional treatments such as soaking, boiling, roasting, and fermentation should be applied to underutilized legumes like jack bean and velvet bean to remove or minimize anti-nutritional factors and improve nutrient digestibility.

- Plant breeders should focus on developing improved varieties of velvet bean and jack bean with reduced anti-nutritional compounds and enhanced nutritional quality.
- Agricultural extension programs and policymakers should sensitize farmers and consumers to the economic and nutritional benefits of cultivating and consuming these lesser-known legumes.
- Advanced analytical methods such as HPLC or GC-MS should be employed to identify and quantify the different saponin and flavonoid compounds, clarifying their specific health and functional roles.
- More studies should be carried out to determine the digestibility, amino acid profiles, and performance effects of these legumes in livestock nutrition.

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