



Research Article

Exploring the Potential for Philippine Orphan Legumes to Replace Meat in The Diet: An Evaluation with Reference to The EAT Lancet's Planetary Health Diet Guidelines

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Citation: Yupangco JM (2025) Exploring the Potential for Philippine Orphan Legumes to Replace Meat in The Diet: An Evaluation with Reference to The EAT Lancet's Planetary Health Diet Guidelines. Food Nutr J 10: 323. DOI: 10.29011/2575-7091.100223

Received Date: 03 April 2025; **Accepted Date:** 08 April 2025; **Published Date:** 11 April 2025

Abstract

The over consumption of meat, sugar-sweetened, and over processed food has led to a rise in non-communicable diseases in the Philippines. Pork, the preferred meat, is consumed by people in all stages of life. Studies have shown that a reduction of meat intake will be beneficial both to human health as well as the environment. In 2019 the EAT Lancet Commission released a reference diet, called the Planetary Health Diet, which placed a large emphasis on reducing the intake of animal protein and increasing the consumption of based plant-based protein. In the Philippines, there are several orphan legumes crops available that are rich in protein and have the potential to replace meat in the diet. These orphan legumes are underutilized for various reasons, including preference, cost, availability, and accessibility. This project reviewed literature to determine the feasibility of including three orphan legumes, cowpea (*Vigna unguiculata*) pigeon pea (*Cajanus cajan*) and rice bean (*Vigna umbellata*) in the Philippine diet to increase legume consumption according to the prescribed amount in the EAT Lancet reference diet. By examining the protein bioavailability, macro and micronutrient content and cost, it was determined that cowpea has the most potential of these orphan legumes to be included in the Filipino diet to reflect the intake of legumes in the EAT Lancet diet.

Keywords: Orphan Legumes; Planetary Diet; Cow Pea; Pigeon Pea; Rice Bean; Nutrition

INTRODUCTION

The rise in over nutrition, the double burden of malnutrition, coupled with climate change mitigating efforts has seen the rise in recommendations for plant-based diets with a reduction of red meat consumption. In 2019, The EAT Lancet Commission produced a reference diet, called the Planetary Health Diet (PHD) that was established to develop global scientific targets based on the best evidence available for healthy diets and sustainable food production. The report had accompanying dietary guidelines that outlined the components for a healthy, planet friendly consumption per day, and is described as a "healthy reference diet which largely consists of vegetables, fruits, whole grains, legumes, nuts, and

unsaturated oils, includes a low to moderate amount of seafood and poultry, and includes none or a low quantity of red meat, processed meat, added sugar, refined grains, and starchy vegetables" [1]. The diet aims to reduce unhealthy eating patters by 2050 and aims for a 50% reduction in unhealthy food, specifically red meat, and sugar, to prevent diet related obesity and non communicable diseases such as cancer, diabetes and cardiovascular disease. Willet et al. (2019) [2] cite that in their meta-analysis, results showed that consumption of processed and unprocessed red meat was associated with a risk of death and cardio vascular disease, while other studies showed an increased risk of type 2 diabetes. They also found that in a pooled analysis of Asian cohort studies, pork was inversely associated with all cause mortality. The risk of cardiovascular disease comes from the constitution of animal protein which combines protein and fat. In the Philippines,

Angeles- Agdeppa et al. (2020) [3] found that contributions to the total fat intake were made mainly by the consumption of pork. Barnard & Leroy, (2020) [4] also found those who consumed any processed meats (specifically salted fish and frankfurters) were 38% more likely to develop diabetes.

In the Philippines, Angeles- Agdeppa et al. (2020) [3] identified three dietary patterns in Filipino adults: meat and sweetened beverages pattern (MSB), a rice and fish pattern (RF), and a fruits, vegetables, and snack pattern (FVS). They found that those with Non-Communicable Disease (NCD) risk factors consumed the MSB dietary patterns and were associated with obesity, diabetes, and dyslipidaemia while the RF diet showed associations with cardio metabolic risks. All diets were also associated with higher intakes of fat, energy, and sugar. Furthermore, they found the pattern of consumption among the adult population is associated with the consumption of processed food with high amounts of sugar, salt and fat. The study also found other indicators of NCD such as the prevalence for elevated blood pressure (19.2%) (DOST FNRI National Nutrition Survey [NNS], 2018), total cholesterol (18.6%), LDL-cholesterol (21.9%) and triglycerides (17.7%) (NNS, 2013). Angeles-Agdeppa et al., (2020a) [3] acknowledged that the low per capita consumption of fruits and vegetables of Filipino adults, of 41 g and 114 g per capita respectively, has put more Filipinos at risk for non-communicable diseases which are the top causes of mortality in the Philippines at 67%. The four major NCDs in proportion to mortality are cardio vascular (35%), cancers (10%), respiratory (6%) and diabetes (4%).

The PHD proposes the inclusion of legumes in the diet as a source of protein. Legumes are known to be a good source of plant protein and can help meet daily requirements of humans in lieu of animal protein [5,6]. Legume grains contain between 17 to 40% more protein compared to cereal grains, and contain vitamins and minerals such as folate, calcium, magnesium, potassium, niacin, and zinc [7]. Legumes also contain iron (5.3-8.5 mg/100g) which is an important mineral for those suffering from iron deficiency in the developing world and is important in a diet that is more plant based [7,8]. Further, legumes contain a high proportion of protein, carbohydrates and fibre which increase satiety [9]. They are a good source of soluble and insoluble fibre, which are essential in lowering cholesterol (Ramulu et al.,1997 in [10]. Their nutraceutical properties include benefits to cardiovascular health, reduction of cancer risk, weight control, and increased insulin sensitivity [11]. Cowpeas, for example been found to have beneficial effects on controlling plasma cholesterol [12].

The Philippines is home to a variety of nutrient dense legume crops that are a potential solution to diet diversity that can be beneficial to overall health. These crops are referred to as under-utilized, under-exploited, underdeveloped, neglected, orphan or indigenous and are under researched, but believed to have high

nutrient and micronutrient contents [13]. Orphan legumes are nutritious, resilient, well adapted to extreme weather shocks and harsh climates. Philippine food historian Felice Sta. Maria (n.d.) [14] notes that Spanish chroniclers Noceda and Sanlucar listed “frijoles” or beans as being eaten by native Filipinos over four hundred years ago. These included *caguios*, now known as *Kadyos* or Pigeon pea and *tapilao*, now spelled *tapilan*, and is rice bean in English. Native Filipinos 7000 years ago ate hunted wild pig and served them at special occasions, where this was reserved for special occasions such as when Pigafetta, (the Italian chronicler who accompanied Ferdinand Magellan when discovering the Philippines) and his crew feasted on pork, sent by the native king to Magallanes (Pigafetta's superior) on the first Easter Sunday in Philippine territory. Today, pork is the main source of animal protein in the Filipino diet as presented by the National Nutrition Survey of 2018 (NNS 2018). The term ‘*Binulay cata lamang, magpatsuad ca*’ meant “Pardon me that I invite you to [eat] only beans [14]. Perhaps this is why culturally, Filipinos place a high value on meat on the table, where the lack of it signifies being in need. Literature shows that the orphan legumes, cow pea (*Vigna unguiculata*), Rice Bean (*Vigna umbellata*) (*tapilan*) and Pigeon Pea (*Cajanus cajan*) (*kadyos, kardis*) are the most widely available in the Philippines. Currently, there is no available research that studies the potential for Philippine orphan legumes to be a source of plant protein within the guidelines of the PHD. There is also no known research that compares the nutritional value of orphan legumes to the most widely eaten source of meat in the Philippines, which is pork. This piece of research based on evidence from literature, aims to assess the viability of adding cowpea, pigeon pea and rice bean to the Filipino diet, to increase the intake of legumes in lieu of pork as the main protein source and to assess their nutrient availability, to create a healthy and diverse diet.

Materials and Methods

A systematic review using the PRISMA framework was carried out to assess literature on the subject. A comprehensive search for literature to be reviewed was performed using electronic databases: AGRIS, Ovid Cab Abstracts, Web of Science. The PICO method was used to create search strings and was broken down as follows: P- Filipinos, I- any intervention C-comparison to any country, O-benefits to nutrition. From this, the following search strings were developed: “legumes human nutrition”, “legumes human nutrition benefits”, “legumes protein human diet” “legumes sustainable diet” “Philippine legumes”. The initial search was limited to the years 2000-2021 to collect recent data, but this proved to be too restrictive in terms of search outcomes. Subsequent searches were not restricted by date. After the primary search, it was evident that cowpea pigeon pea and rice bean had the most available literature. A secondary search with the following terms was then made: “cowpea nutrition”, “rice bean nutrition”, “pigeon pea nutrition.” As this study looks at the possibility of replacing legumes with

animal protein, a search for the benefits of animal protein was also undertaken using the following terms “meat protein” “animal protein benefits”. A search was done for “sustainable diets” was entered as a search to compare them to the prescribed EAT Lancet reference guide; the search terms used were as follows “sustainable diet*” “plant-based diet” “vegan” “vegetarian”. A tertiary search for “cow pea, pigeon pea and rice bean- cholesterol and type 2 diabetes was also done, as the initial search showed the potential for nutraceutical value of these legumes.

These searches resulted in 6085 studies, which were screened for significance and relevance to the topic. Broadening the search proved to be valuable as it brought out studies that did not have the relevant titles but when screened, had valuable information. Since the date was also left blank, it brought up several older studies from the 1980’s and 90’s which proved to be useful as these older studies provided a basis for the background of newer studies. A report from Eusebio et al. (1975) [15] from the University of the Philippines Los Baños identified cowpea, pigeon pea and rice bean as orphan legumes that could be used to diversify nutrition for Filipinos and was key lead in the search.

The exclusion criteria for the first screening were as follows: articles that related to: communicable diseases, diet in relation to a fad diet, transient physiological conditions (i.e., pregnancy), behaviours and attitudes related to food and food preparation, environmental impacts of legumes, and studies pertaining to legume consumption.

To further deepen the scope of research, the multi-source method of Onwuegbuzie et al. (2012) [16] was adapted as it provides a broader definition of a literature review by stating that the literature could represent any of the following sources: “research articles, opinion articles, essays, article reviews, monographs, dissertations, books, Internet websites, video, interview transcripts, encyclopaedias, company reports, trade catalogues, government documents, congressional/parliamentary bills, popular magazines, and advertisements” [16]. Data for the Philippine diet recommended daily intakes, National Nutrition Survey (NNS) were all taken from the Department of Science and Technology- Food and Nutrition Research Institute’s public website (DOST 2022), where data is available to download. Data on current prices were taken from the Philippine Statistics Authority’s market watch website (PSA 2022) while The Philippine Food Composition Tables of 2019 (PFCT) were used to collect nutritional data on Philippine orphan legumes as well as meat.

The search process was documented with a PRISMA diagram (Figure 1) to keep track of the screening process. To be thorough, the final articles that were included as potential evidence were evaluated using the six levels of evidence based on the classification system of Shadish, Cook and Campbell (2002) and Petticrew and Roberts (2006) (CEBMA Guidelines for Rapid Evidence

Assessments). The grading criteria for these articles were adapted from Shadish, Cook and Campbell (2002) (Table 1).



Figure 1: Prisma Diagram for literature search.

Systematic review, meta-analysis of randomized control studies	AA
Systematic review or meta-analysis of randomized controlled and/ or before-after studies	A
Randomised control studies	
Systematic review or meta-analysis of controlled studies without a pre-test or uncontrolled study with a pre-test	B
Nonrandomised controlled before -after study	
Interrupted time series	C
Systematic review or meta-analysis of cross-sectional studies	
Controlled study without a pre-test or uncontrolled study with a pre-test	D
Cross sectional study (survey)	
Case studies, case reports, traditional literature reviews, theoretical papers	E

Table 1: Grading of evidence Shadish, Cook and Campbell (2002) and Petticrew and Roberts (2006) (CEBMA Guidelines for Rapid Evidence Assessments).

Results

Results from the literature search showed that cow pea, rice bean and pigeon pea are the most available orphan legumes found in the Philippines. The three orphan legumes were heavily studied in China, India and other regions in South East Asia for their nutritional and nutraceutical properties, where search results yielded several studies. It was valuable to show the number of

studies that particularly mention the names of the orphan legumes for review as this reflects the importance and status of each legume and the resources that have gone into their study (Figure 2). While pigeon pea reflects the highest number, in the Philippine context, it did not translate to pigeon pea as the most viable popular or usable legume as most of the pigeon pea studies were from India, where it is a large part of their diet.

The preference for pork in the Philippines was evident from the literature search, therefore, pork was chosen to represent the meat protein that would be compared against orphan legumes and evaluated to compare their nutritional compositions. In analysing the suitability of orphan legumes to replace meat, data was collected from the Philippine Food Composition Table of 2019 (PFCT 2019) to compare macro nutrients in cowpea, pigeon pea and rice bean. As this project aims to explore substituting orphan crops for pork intake, pork shoulder and pork belly were chosen as the pork cuts to be represented as the most widely consumed cuts as these are monitored by the department of Agriculture’s daily price watch (DA 2022) and their nutritional value was also taken from the food composition tables to compare them with the orphan legumes.

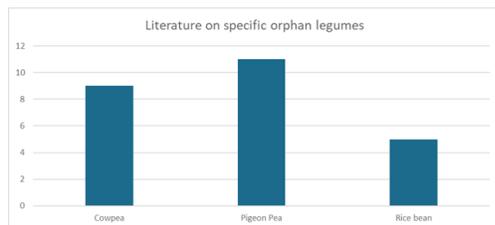


Figure 2: Literature on specific orphan legumes.

Discussion

Cowpea (*Vigna unguiculata*) (*paayap*)

In the Philippines, the National Plant Genetic Resources Laboratory (NPGRL) of the Institute of Plant Breeding (IPB), College of Agriculture and Food Science (CAFS), University of the Philippines Los Baños (UPLB), cowpea has 600 recorded accessions as of 2020. Cow peas, sometimes referred to as black eyed peas/beans, are important legumes in tropical and subtropical regions, especially in Africa, and are used for human consumption as well as animal feed [17]. The ratio of essential amino acids in relation to total amino acids suggests that cowpea has the potential to cover the nutritional requirements of humans [18]. Like many legumes, the limiting amino acids in cowpea are methionine and cysteine. In terms of crude protein content, cowpea has the highest among the three orphan legumes, at 20.4 g at dry weight (Philippine Food Composition Table [PFCT], 2019) The nutritional value and texture of cowpea are influenced by storage conditions [19], where they found that cowpeas stored in warm temperatures were yielded

low invitro protein digestibility and exhibited a ‘hard to cook’ defect, compared to cow peas stored in cool temperature.

Cowpea processing

Akinyele and Akinlosotu [20] found that four-hour soaking led to a 49.9% decrease in verbascose, 29.8% stachyose and 1.0% in raffinose. Dehulling led to a decrease of 76.4% in verbascose, 16.9% in stachyose and 56% in raffinose, 63.6% in glucose and galactose and a 45.9% increase in sucrose. Two methods studied by Laurena et al. (1987) [21] were (A) continuous boiling water and (B) hot water added to boiling water which resulted in significant differences in changes in *in-vitro* protein digestibility (IVPD) and polyphenol removal from cowpea seeds. Method A removed 6-12% of polyphenols and improved IVPD by 60-81% while method B removed 80-86% of polyphenols and improved IVPD by 20-26% [21]. This simple technique which can be practiced at the domestic level, can have a significant impact on nutritional quality of the legumes. Pereira et al. (2014) [8] investigated the best methods for retaining iron and zinc in cowpea and found that soaking followed by cooking with a regular pan retained iron, while using soaking then pressure cooking retained zinc.

Pigeon pea (*Cajanus cajan*) (*kadyos, kardis*)

The Pigeon Pea Project headed by the International Crops Research Institute for Semi Arid Tropics [ICRISAT] has planted improved varieties of pigeon pea across the Philippines as part of an initiative to promote pigeon pea as a food legume for resource poor farmers [22]. Second in the most number of accessions to cowpea, NPGRL records 566 accessions as of 2020. Pigeon pea is considered an important grain legume, prompting the UN to instigate more research into the pigeon pea for providing protein in developing nations [23]. Protein content of 43 common varieties of pigeon pea ranged from 17.9 and 24.3 % Singh, 1993 [24] while Dhal (split pea) found that the protein content of pigeon pea ranged from 19.7% to 28.2% across different varieties. Mature pigeon pea was found to have a higher protein concentration compared to younger pods (Singh & Eggum, 1984) [25] Polyphenols of pigeon pea are concentrated in the seed coat; removing the seed coat by dehulling is the most efficient way to get the nutrients needed [24]. In the study by Sousa et al. (2020) [26], using the INFOGEST static model, pigeon peas showed to have the second highest value (compared to whey protein isolate) of glutamic acid equivalents, which were in line with calculated protein digestibility in protein digestibility corrected amino acid scores PDCAAS and *in vivo* DIASS values.

Pigeon pea processing

Germinated pigeon peas were found to be useful in lowering oxidative stress and led to reduced fasting blood glucose levels in diabetic rats (Uchegbu & Ishiwu, 2016) [27] After 48 hours of

germination, the protein digestibility corrected amino acid score (PDCAAS) of pigeon pea flour and protein isolate increased (Ohanenye et al., 2021) [28] Germination for 48 hours also increased the value of net free amino acids as well as a 32% increase in flour protein digestibility. Sharma et al. (2019) found that germination at different temperatures and lengths of time also changed biochemical compounds in pigeon pea, increasing antioxidant activity, metal chelating activity, in vitro protein digestibility (IVPD), in vitro starch digestibility and increased flavonoid content. Further germination for 5 days increased the iron, calcium, magnesium and phosphorous in pigeon pea [29].

Rice bean (*Vigna Umbelatta*) (tapilan)

Rice bean has been gaining attention world-wide for its high yielding ability and resistance to viral, fungal and bacterial diseases [10]. NPGRL records 117 accessions as of 2020. It is a source of protein at 18.4g at dry weight, with high methionine, tryptophan, calcium and iron and are native to Southeast Asia and the Philippines, Burma, Malaysia, China, Indonesia, Philippines and India [30]. Rodriguez and Mendoza (1991) [31] found rice bean to have the following properties: in vitro protein digestion (IVPD) 82-86% for seed meal, a protein content of 17.26 to 31.42%, fat 3.46 to 4.03% and 3.99 to 4.58% for carbohydrates as compared to protein digestibility found to be 58.4% in whole rice bean seeds by [32]. Although both Rodriguez and Mendoza (1991) [31] and Saharan et al. (2004) [32] made use of the micro-Kjeldahl method with factor of 6.25 applied to convert the amount of nitrogen to crude protein, different varieties of rice bean were used, with Rodriguez and Mendoza (1991) [31] making use of Philippine rice bean and Saharan et al. (2004) [32] using a high yielding variety. The results of these two experiments potentially show a higher IVPD from Philippine varieties compared to the high-yielding seeds of rice bean (RB-32) from India used by [32]. When examining the vitamins and minerals in orphan crops, the calcium and phosphorous content of rice bean stands out among all others (Table 2). Iron has multiple important functions in the body that regulate the use of oxygen in the muscles, enzyme function and supporting metabolism [33]. Iron in the diet come in two forms, haem, and non-haem. Both kinds of iron are found in animal derived food, with haem being more bio available, while plant derived food only has non-haem. Haem iron’s absorption rate is 15-40%, while non-haem is at 1-15% (Hunt 2003 in Bohrer 2017) [33].

Rice bean processing

Dehulling and soaking were shown to have the best results in terms of improving nutrient content and reducing anti nutrients in rice bean. Soaking improved IVPD (Saharan et al., 2004) [32] while dehulled, soaked and pressure-cooked rice bean had 54.6% bioavailability for iron [30]. Soluble zinc was highest in dehulled,

soaked, pressure cooked rice bean at 28.2%, Maximum retention for zinc in dehulled, soaked, pressure cooked at 63.37, followed by sprouted for 48h, and pressure cooked at 61.38% [30].

Orphan legume	Ideal storage method or form	Ideal Processing
Cowpea	Cold, dry cow pea	Cook time: 45 minutes Removal of anti-nutrients: start with hot water, then add boiling water when cooking Removal of hard to digest properties: soak for four hours then dehull.
Pigeon pea	Dry pigeon pea	Germinating for two to five days, where fifth day yields greatest benefits for protein digestibility, and nutrient availability.
Rice bean	Dry rice bean	Soak to increase in vitro protein digestibility Dehull to improve nutrient content

Table 2: Ideal methods for processing cow pea, pigeon pea and rice bean.

Comparing the PHD to the Philippine Diet

The NNS (2018) found that Filipinos consume a total of 985.3 g of animal products in one day including meat, fish, poultry, eggs, milk, and dairy products. (Figure 3) The survey also reported that pork is the top source of animal meat that is consumed daily in the Philippines across all age groups. (Figure 4) The PHD classifies legumes and animal sources of protein together, limiting beef, lamb, or pork to a maximum of 28 g per day, chicken, and other poultry to 58 g per day, fish to 100 g per day and eggs at 13 g per day. Legumes are also capped at 100 g per day. All the protein sources are interchangeable with a maximum of 386 g per day.

A comparison was made between the findings in the literature on the PHD recommendations and the Philippine mean one day intake of food groups using the data from the 2018 National Nutrition Survey (Table 3). The NNS chart does not distinguish between whole grains or processed food made from grain and therefore shows a very high number. Animal protein intake is also significantly higher in the Philippine diet, while sugar intake is relatively the same. Vegetable intake was reported to be higher in the household consumption survey but is not evident in the individual survey (Figure 4) which shows no vegetables as a source

of energy. As the NNS is a self-reporting modality, it is often biased due to wanting to produce a socially desirable outcome such as healthier eating [34].

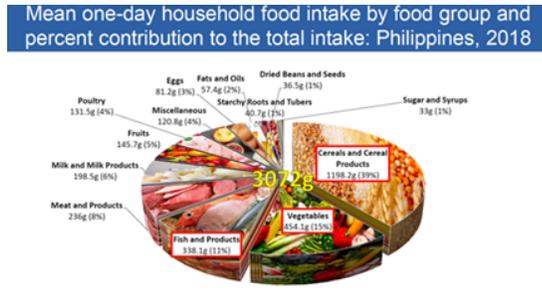


Figure 3: National Nutrition Survey 2018 of mean one day household intake by food group in % intake.



Figure 4: Top 5 Food Sources of total Energy Intake, National Nutrition Survey 2018.

Currently, Filipinos across the nation consume on average 36.5 g of dry legumes per day compared to the PHD’s recommendation of 75 g (dry) as the recommended intake, with a maximum of 100 g per day. This is slightly better than the current world wide average of 21 g/ (Semba et al., 2021) [35] but not enough to meet the EAT Lancet’s recommendations. Increasing the consumption of legumes in the Filipino diet can potentially be a solution to increase diet diversity and improve nutrition [36]. To find the divergence in

percentage the Philippine dietary intake as compared to the EAT Lancet recommendation (Table 4), the following equation was used:

$$(x/y)*100-100$$

x=EAT Lancet average per day (g)

y= Mean one day household food intake, National Nutrition Survey 2018 (g)

The results reveal the difference over or under the Philippine diet compared to the recommendations of the PHD, with numbers highlighted in bold, indicating the gap in percentage below the PHD recommendations, while the other numbers indicate the percentage over. Results in table 1 show a large divergence for the intake of all animal products, with beef, lamb or pork at 1,585.71%, while fish is over by 1,107.50%. On the other hand, a 51.33% increase in legumes is needed to meet the recommendations of the PHD. This 51.33% increase would ideally reduce the intake of animal sourced proteins. As the PHD is a predominantly plant-forward diet, it is good to note that the Philippine intake of vegetables is a little bit over the recommendations by 51.37%. Chaudhary and Krishna (2019) [37] used an optimization algorithm to find out how much of a reduction or addition of a certain food group (g/capita) was needed to meet the recommendations of the PHD. They found that in the Philippines, there is a need to reduce the consumption of (g/capita) of pig meat (-23) and poultry (-10). While the Philippine mean daily intake does not distinguish processed cereals and whole cereals, Chaudhary and Krishna (2019) [37] found the need for the reduction of rice by 281 points, sugar by 43 points, processed wheat flour by 21 points but an increase of 244 points for whole wheat flour. These findings reflect the findings of the NNS 2018 Individual intake survey, which shows the consumption of rice, pork, sweetened food and oil across all ages and demographics (Figure 4). Chaudhary and Krishna’s (2019) [37] algorithm also indicated that the pulse intake in the Philippine diet should increase by 71g per capita per day [37]. If this is combined with the current daily average intake of 36.5g, the new total of 107.5 g would be almost equal to the PHD’s recommendation of 100 g maximum per day.

Food Group	PHD recommendations (g) per day	Mean one day household food intake, National nutrition survey 2018 (g)
Grains, cereal products	222	1198.2
Tubers or Starchy Vegetables	50	40.7
All Vegetables	300	454.1
Fruits	200	145.7
Dairy	250	198.5
Beef, Lamb, Pork	14	236
Chicken	29	131.5
Eggs	12	81.2
Fish	28	338.1
Legumes	75	36.5
Nuts	50	0
Unsaturated oil	40	57.4
Saturated Oil	11.8	0
All sugar	31	33

Table 3: PHD compared to NNS in grams.

Food Group	% Difference from Planetary Health Diet Recommendation
Grains, cereal products	439.79%
Tubers or Starchy Vegetables	-18.60%
All Vegetables	51.37%
Fruits	-27.15%
Dairy	-20.60%
Beef, Lamb, Pork	1585.71%
Chicken	353.45%
Eggs	576.67%
Fish	1107.50%
Legumes	-51.33%
Nuts	-100%
Unsaturated oil	43.50%
Saturated oil	-100.00%
All sugar	6.45%

Table 4: Divergence of the Philippine diet from the PHD in %.

Protein

The importance of protein is argued by Aiking & de Boer, (2020) [38] to be the leading cause of undernutrition rather than the lack of calories. (Rodriguez & Mendoza, 1991) [31] found rice bean to have 17.26 to 21.42% protein while *in vitro* protein digestibility (IVPD) ranged from 82 to 86% for the seed meal, which was higher than mung bean (80%) and cow pea (74%). Pigeon pea also appears to have the lowest protein content among the selected legumes [39].

When exploring a shift in protein source, essential amino acids which make up protein should be considered. Plant proteins were shown by Pellet and Young (1990) in Sousa et al (2020) [26] to either be lacking one or more essential amino acid (EAA) or have a complete EAA but with limited amounts of sulphur amino acids (cysteine and methionine) [26]. The ratio of essential amino acids in relation to total amino acids suggest that cowpea has the potential to cover nutritional requirements of humans [18].

Data was collected from the Philippine Food Composition Tables (2019) to compare macro nutrients in cow pea, pigeon pea, rice bean and pork shoulder (Table 5). Pork shoulder and pork belly were chosen as the pork cuts to be represented as the most widely consumed cuts as these are monitored by the department of Agriculture's daily price watch.

The Philippine Recommended Daily Intake (RDI) of protein for Filipino adults is 71 g for males and 62 g for females (DOST FNRI 2018). When computed, the recommended protein in the Philippine Dietary Reference table comes out to 0.852 g protein per kg of body weight for men, and 0.846 g per kg of body weight for women. This exceeds the Food and Agricultural Organization (FAO) recommendation of the 0.75 g /kg as recommended by FAO, but comparable to the intake of 0.8 g/kg as reported by (Drulyte & Orlien, 2019) [40] and 0.8 g/kg by World Health Organization (WHO). FAO finds that protein digestibility in animal sources such as meat and milk are higher than that of beans. This is due to the protein structure and release of bioactive sequences requires further study because of their complex relationship and potential inverse reactions when combined with reactions from starches and fibres in the legume. Plant proteins were shown by Pellet and Young (1990) to either be lacking one or more essential amino acid, or have a complete EEA but with limited amounts of sulphur amino acids (cysteine and methionine) [26]. The lack of cysteine and methionine is seen in Philippine cowpea, rice bean and pigeon pea. In general, it is believed that heat treatment improves protein digestibility and micro and macro nutrients as reflected in studies by [7,18,21,41-43]. However, Avanza et al. (2013) [44] did not find this to be true. Across varieties, physiochemical environments vary, as do the localisations of nutrients, the interactions within each seed between zinc iron calcium magnesium with proteins

also affect the absorption [44]. Avanza et al found that all varieties tested had a protein reduction of 0.3-7% when autoclave treatment, and 3-6% reduction when cooked at 100 C at 60minutes. For some varieties there was a reduction in carbohydrates of 35% with heat, while protein and nitrogen compounds are lost due to amino acid oxidization, while carbohydrates are lost due to solubility in water. Potassium, Magnesium and Iron decreased, but zinc increased with thermal treatment.

Cowpea protein

Most of the cowpea protein is made up of globulins, albumins, glutelin and prolamins and have a prevalence of glutamine and is an excellent source of lysine. Like most legumes, their limiting amino acids are methionine and cysteine. The ratio of essential amino acids in relation to total amino acids suggest that cowpea has the potential to cover nutritional requirements of humans. (Gonçalves et al., 2016) [18] In terms of crude protein content, cow pea the PFCT records cow pea to have 20.8g of protein per 100g.

Rice bean Protein

Rodriguez and Mendoza found rice bean proteins to have 17.26 to 21.42% protein, while *in vitro* protein digestibility (IVPD) ranged from 82 to 86% for the seed meal, which was higher than mung bean (80%) and cow pea (74%) [31]. Figure 6 shows that accession 46 of Philippine rice bean to have the highest protein content. The PFCT records rice bean to have 18.4g of protein per 100.

Pigeonpea Protein

The protein content of pigeon peas was found to be varied according to planting area, over different locations and different months and was largely dependent on soil nutrition and climate. The PFCT officially records protein content of dry pigeon pea to be at 21.2g pf protein per 100g. The same can be said of pigeon peas in the Philippines which grow in the Norther part of Luzon Island and in the Visayas region, and are two different varieties. Pigeon pea also appears to have the lowest protein content among the selected legumes [39].

Micronutrients

Increasing legume consumption could present people with different options other than animal protein as legumes contain a high proportion of protein, carbohydrates and fibre which increase satiety (Kristensen et al., 2016) [9] while increasing their micronutrient intake. Legumes are a good source of soluble and insoluble fibre, which are essential in lowering cholesterol (Ramulu and Udayasekhara Rao 1997 in [10].

When examining the micronutrients in orphan crops, the calcium and phosphorous content of rice bean stands out among all others

(Table 6). Iron has multiple important functions in the body that regulate the use of oxygen in the muscles, enzyme function and supporting metabolism [33]. Iron in the diet come in two forms, haem and non-haem. Both kinds of iron are found in animal derived food, with haem being more bio available, while plant derived food only has non-haem. Haem irons absorption rate is 15-40%, while non-haem is at 1-15% (Hunt 2003 in [33]).

The iron content of all three-orphan corps is higher than pork (Table 5). The iron content is particularly important in the Philippines, as the country has put high value on increasing iron intake, particularly by fortifying widely eaten food, such as rice, to combat iron deficiency anaemia which is prevalent among infants 40.5%, (40.5%), pregnant women (26.4%), lactating women (16.7%), and elderly males (23.0%) in the country and was found to have a profound effect on the first 1000 days of life [45]. In the 2013 Biochemical survey by DOST FNRI, iron deficiency anemia among the general population was deemed as ‘mild’ affecting 11.2% over all prevalence [46]. The daily requirement of iron for adult’s ranges from 12-28g per day and 30-38 mg per day for pregnant and lactating women (Palanog et al., 2019) [45], increasing the consumption of orphan legumes, and cow pea in particular, can help meet the iron needs.

Food	Energy (Kcal)	protein (g)	Total Fat (g)	Total Carbohydrate (g)	Total dietary fibre (g)
Cowpea	358	20.4	1.5	65.8	11
Pigeon Pea	125	5.7	0.6	24.3	6.8
Rice bean	356	18.4	3.1	63.7	16
Pork Shoulder (Kasim)	387	13.4	37	0	0
Pork Belly (Liempo)	393	14.5	37.2	0	0

Table 5: Macronutrients in Orphan Legumes and Pork.

Food	Sugars (g)	Sodium (mg)	Calcium (mg)	Phosphprous (mg)	Iron (mg)	Retinol (ug)	Bcarotene (ug)	Vit A (ug)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)	Vit C (mg)
Cowpea	7.1	15	64	365	6.5	0	5	0	0.65	0.31	2.1	0
Pigeon Pea	2.8	5	45	119	1.1	0	11	1	0.27	0.06	1.1	0
Rice bean	6.5	9	400	236	4	0	0	0	0.54	0.17	2.2	0
Pork shoulder	0	61	16	112	0.9	5	0	5	0.35	0.16	3.2	3
Pork liempo	0	40	15	157	1	50	0	50	0.4	0.13	4	1

Table 6: Select micronutrients in orphan legumes and pork.

Non-Communicable Diseases

Legumes are known to have several nutraceutical properties that can help reduce the occurrence of non-communicable diseases. This is particularly significant in the Philippines where type 2 diabetes, cardiovascular diseases and liver and kidney disease is prevalent, due to the consumption of unhealthy food. Cowpea has gained attention world-wide for its health benefits that include having anti-diabetic, anti-cancer, anti-hypertensive and anti-inflammatory properties and have been proposed to be consumed in place of meat to prevent chronic disease [47]. Phenolic compounds found in higher amounts in red cowpea have been associated combatting cardiovascular disease and cancer and are reported to have high levels of antioxidants. Hachibamba et al. (2013) showed that cowpea extracts inhibited LDL oxidation, possibly due to the phenolic content, suggesting that cowpea consumption can be beneficial in the prevention of cardiovascular disease.) [12]. found that whole cowpea seeds were effective in modulating lipid metabolism in hamsters, making this promising benefit for human consumption.

Uchegbu et and Ishiwu (2016) [27] found that germinated pigeon peas fed to diabetes induced rats lowered the instance of hypoglycemia, indicating that germinated pigeon pea can help to control diabetes [27]. The same study also found that germinated pigeon pea was beneficial in lowering lipid pre-oxidation, which is a prelude to cell death; Alzheimer’s is one such disease that is characterized by lipid pre-oxidation. Around the world, Pigeon pea has been part of traditional medicine that treats a range of ailments from vertigo using scorched seeds, kidney ailments using immature seeds, as a cure for inflammation and blood disorders in South America, Mexico and China [39]. Adding these legumes to the Filipino diet can help with the prevalence of non-communicable diseases.

The Cost of Adding Orphan Legumes to the Filipino Diet

Rathnayaka et al. (2021) found that Filipinos spend 17% per annum of their budget on meat-based proteins compared to less than 12.07% in neighbouring Asian countries. They also found that in the period of 1990-2013, animal derived commodities have also risen by 2.52% in the Philippines. To meet the increasing demand for meat, the Philippines is reliant on meat imports from countries including Australia, Canada, New Zealand, France, and the United States. As of April 2022, imports have amounted to 421973.137 tonnes of pork, 224121.618 tonnes of chicken and 99826.401 tonnes of beef (Bureau of Animal Industries (BAI) 2022).

The EAT Lancet reference diet has been criticised for its lack of affordability, with the cheapest iteration of the diet using a global median costing \$2.85 (£2.21) per day [48]. Filipinos spend on average PhP 276.1 pesos per day on food (DOST FNRI, 2019) (Figure 5) equivalent to approximately £3.73, higher than the

global median, with an average of P107.6 spent on fish, meat, and poultry, this suggests that Filipinos could afford to switch to the EAT Lancet recommended diet, and that affordability would not be a major factor in the change of diet. Hirvonen et al also found that the EAT Lancet diet was a more expensive way to hit the minimum nutritional adequacy requirement, citing cheaper sources of food to achieve the requirement, and looked at locally available food sources to comply with the EAT Lancet’s guidelines and found that a large proportion is spent on animal protein at 39%. The most expensive component of the diet came from fruits and vegetables at 31.2%, followed by legumes and nuts at 18.7%. All animal sourced food made up 32.8% in low-income countries [48]. In the Philippines, animal sourced food makes up 47% of the total amount spent on food, making it substantially higher than the world average, while the percent spent on legumes is much lower than other countries. Figure 6 suggests that cowpea yields a higher number of grams as well as available calories per at the cost of PhP 107.



Figure 5: Mean one day household food cost, NNS 2018.

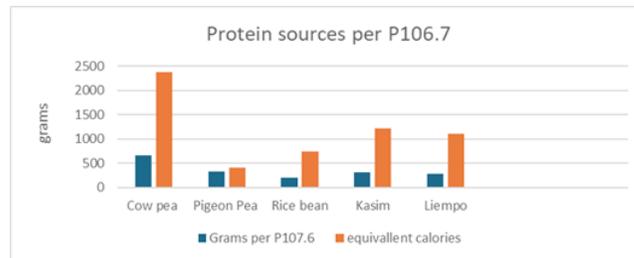


Figure 6: Grams of protein per P107.6 Legumes per dried weight, pork per fresh as indicated in the Philippine Food Composition tables. These values were used as the legumes are available dried at the market, while pork is fresh. The comparison is made for what can be purchased at the market. Sourced from Philippine Food Composition Tables 2019.

Barrier to consumption: Legumes and Gout

For the Philippine context, it is important to address the cultural belief that eating legumes causes gout and is a very real barrier to the consumption of legumes. Jakse et al. (2019) [49] also observed a hesitancy by both medical practitioners and patients to consume

high purine vegetables because of the high purine content and uric acid generation potential. While vegetables such as broccoli, kale and legumes have a relatively high purine content and can increase uric acid accumulation, higher purine content is found in animal meats, fish and visceral organs such as liver (B.Jakse, B.Jakse. M. Pajek, 2019) [49]. Using the data from the Singapore Chinese Health Study of 63,257 Chinese people living in Singapore, Teng et al found that they had a higher total dietary protein intake from mainly poultry and fish/shellfish was associated with an increased risk of gout, while dietary intake of soy and non-soy legumes was associated with a reduced risk of gout [50]. Furthermore, Jakse et al. (2019) [51] found that transitioning from a Western style diet to a plant-based diet, even with higher purine content, did show a minimum increase in serum uric acid, but still well within range. It is worth noting that participants in the Chinese Health study who developed gout also had high levels of total protein consumption including red meat (including pork, beef and lamb), poultry, and fish and shellfish at baseline than those who remained gout free. Another long-term study done in Taiwan followed 4903 participants in the Tzu Chi Health Study (Cohort1, recruited in 2007e2009) and 9032 participants in the Tzu Chi Vegetarian Study (Cohort2, recruited in 2005) until end of 2014 to explore the effects of a vegetarian diet and the risk of gout [51]. This study found that the consumption of protein from animal sources caused higher levels of serum uric acid than from a vegetarian diet. To corroborate this, Jakse et al. (2019) [49] categorise beans and lentils to have low purine content at 50-100mg/ 100 g and therefore have a low risk of developing high uric acid. Diets rich in plant foods that have high purines were not associated with increased risk of gout and hyperuricemia, even when soy products were consumed (Jakse et al 2019) [49]. Interestingly, Chiu et al. (2020) [51] found that a pure plant-based diet did not have the lowest instance of gout and uric acid, and that lacto-ovo vegetarians had the lowest uric acid concentration, followed by vegans, then nonvegetarians (men: 6.05, 6.19, 6.32 mg/dL, respectively; women: 4.92, 4.96, 5.11 mg/dL, respectively) [51].

Conclusion

Cow pea and pigeon pea were found to be viable options as crops to consume to replace the intake of meat, while rice bean was not, due to the lack of supply and availability. Based on the research presented in this project, cow pea is the most viable orphan legume that can fill the gap of 51.3% more legumes per day to conform to the Eat Lancet Reference guide. Cow pea is the most available, with the highest protein content, and best value for money. Cow pea also contains properties to combat high cholesterol, with a ratio of essential amino acids in relation to total amino acids that makes it a suitable protein source.

Orphan legumes have low market demand and the lack of adequate seed supply coupled with an unusually high cost of labor and low

production yield has turned the farmers attention to more lucrative crops such as rice, maize and in the Philippines, sugarcane (Saka et al in [52]). Food and Agriculture Organization Statistics [FAOSTAT] (2022) records pigeon pea yield in the Philippines to be generally on an upward trend from 12,229 hg/ha in 2001 to 18,773 hg/ ha in 2020. Initiatives such as the Pigeon Pea Project in the Philippines, spearheaded by ICRISAT, proposed planting of pigeon peas in drylands, where they can thrive, and provide food for farmers as well as becoming an income generating crop [22]. Cow pea, on the other hand has experienced high yields of 34,798 hg/ha in 2013 but is seeing a downward trend to 19,020 in 2020, bringing it to similar levels as pigeon pea. There was no available data for rice bean, due to its low yields. Cow pea has a lower harvested area compared to pigeon pea, despite higher yields according to FAOSTAT (2022), which indicates that the plant takes up less space, compared to pigeon pea. The purchase price of orphan legumes fluctuates considerably during the year from Php 200 in harvest time (January to April) to P700 for the rest of the year.

There is also a lack of local availability of essential inputs such as quality seed of improved varieties, Rhizobium inoculum, the lack of proper post-harvest facilities, and isolation from global markets to realise the value of these legumes [53]. Instead, subsidies are made by agro-industrial companies for cash crops as well as artificial inputs. Orphan legumes that are found in the Philippines have been cultivated by local farmers and have undergone extensive local domestication [54]. However, they remain underutilized because they have not found a place on the larger local and global market [55]. In the Philippines, weevil infestation is a very real problem and is a result of a lack of post-harvest facilities and proper treatment. Most weevil infestations are a result of improper drying techniques and storage, resulting in the weevil hatching after it has been bought and stored in homes. Researchers at UP Los Baños Entomology department are researching appropriate low-cost methods to address this issue. Storing newly dried seeds in a container that can produce a vacuum effect, such as a water jug with a screw top, can suffocate any remaining weevil.

Cow pea pigeon pea and rice bean have shown to be viable options to increase the consumption of legumes and even replacing part of pork consumption in the Philippines. Their affordability coupled with their nutraceutical and nutrient dense properties, make their increased consumption a way to reduce the instances of malnutrition and non-communicable disease in the Philippines, as is the goal of the PHD. As the Philippine daily expenditure on food is higher than the mean global average, this research has shown that Filipinos can afford to include legumes to their diet and provide more calories per day compared to meat. Very real barriers of cultural belief still surround the increased consumption of legumes, so an information campaign to promote their benefits,

processing and affordability is needed. These orphan legumes are not widely consumed in the Philippines due to the same barriers faced in other countries such as low demand, poor management practices and a lack of marketing to create a demand [17]. However, due to the rising costs of animal-based protein and an interest in meat alternatives, the potential for orphan legumes as a source of plant protein for the Philippine diet has been shown to be possible and beneficial for people, societies, and the planet.

Acknowledgements

Research in the field of orphan legumes in the Philippines has brilliant women scientists at its forefront, with the desire to provide nutrition to all Filipinos. I would like to thank the women who came before me, and so generously shared their knowledge. Dr. Evelyn Mae Tecson Mendoza, member of the National Academy of Science and Technology, Dr. Imelda Angeles Agdeppa, former director of the Food Nutrition Research Institute of the Philippines, and author of several biochemical analysis of orphan crops, Dr. Corazon Barba, who co-wrote the 1975 report with Eusebio et al., which led to the determination of orphan legumes to be studied in this project, and lastly with Ms. Hydee de Chavez of the National Plant Genetic Resources Library at the University of the Philippines, Los Baños

Ethical Guidelines

Figures from the National Nutrition Survey of 2013 and 2018 were taken from online sources and are publicly available. No other issues ensue.

Conflict of Interest: There are no conflicts of interest regarding the work produced for this paper.

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