Original Article
DOI: https://doi.org/10.70749/ijbr.v3i4.1168

INDUS JOURNAL OF BIOSCIENCE RESEARCH
https://induspublishers.com/IJBR
ISSN: 2960-2793/ 2960-2807

Influence of Wet Processing Techniques (Soaking, Boiling, and Pressure Cooking) on Phytic Acid Reduction, Mineral Retention, and Solubility in Common Beans *Phaseolus Vulgaris L, Vigna Unguiculata, Vigna Radiata, and Cicer Arietinum L.*

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ARTICLE INFO

Keywords
Saoking, Boiling, Phaseolus Vulgaris L, Vigna Unguiculata, Vigna Radiata, Cicer Arietinum L., Phtate concentrations, percent phytate degradation, Mineral solubility

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Declaration
Authors' Contribution: All authors equally contributed to the study and approved the final manuscript.
Conflict of Interest: No conflict of interest.
Funding: No funding received by the authors.

Article History
Received: 08-01-2025 Revised: 01-04-2025
Accepted: 17-04-2025 Published: 30-04-2025

ABSTRACT

Introduction: Beans and chickpeas are one of the most important crops in the world because of their nutritional quality. Phytic acid lowers the bioavailability of minerals. Heat treatment significantly improves nutritional quality in pulses by destruction or inactivation of heat-labile anti-nutritional factor phytic acid. **Methodology:** This study examined four local bean cultivars: Red Kidney beans (*Phaseolus Vulgaris L)*, White beans (*Vigna Unguiculata)*, green mung beans (*Vigna Radiata), and Chickpeas (Cicer Arietinum L.).* These beans were subjected to different domestic processing techniques, including soaking for 1 hour, 6 hours, and overnight, and boiling (until tender and until all water was absorbed). They were also cooked under vacuum in a pressure cooker with and without use of bicarbonate soda. The samples were analyzed for their percentage of phytate content in both raw (as control) and cooked forms, and the mineral content, percent phytate degradation, and percent mineral solubility were determined following standard procedures. **Results:** The effects of domestic processing on the phytic acid content of beans are summarized below. Soaking pulses for 1 hour resulted in varying reductions; mung beans had the highest decrease of 68.3%, followed by white beans at 34.1%, red kidney beans at 22.7%, and chickpeas at only 5.71%. While mung beans significantly decreased from 2.08% to 0.66%, white beans dropped from 1.096% to 0.72%, and red kidney beans from 0.97% to 0.75%. Chickpeas showed minimal change, remaining nearly the same after soaking. After soaking for 6 hours, white beans exhibited the highest reduction at 42.9%, down to 0.63%, while red kidney beans decreased by 33% to 0.65%. Chickpeas had a minimal reduction of 1.43%, remaining nearly unchanged. Mung beans showed an anomalous reduction to -0.02%, warranting further investigation. With 12 hours of soaking, mung beans again showed significant improvement, decreasing to 0.63% (a 69.7% reduction), while white beans reduced to 0.54% (50.7%). Red kidney beans and chickpeas had minimal reductions, suggesting that soaking alone is ineffective for these types. Overall, longer soaking times effectively reduced phytic acid in mung and white beans, while red kidney beans and chickpeas may require additional processing methods for better results. Boiling also resulted in a 59.1% reduction for mung beans, indicating varying effectiveness across different pulses. **Conclusion:** This research has validated the use of soaking and boiling to reduce the phytate' concentrations presumably by rearranging phenolic compounds, which are likely to entrap nutrients such as minerals in chickpeas, mung beans, white beans, and red kidney beans.

INTRODUCTION

Beans belong to the *Leguminosae* family and are considered the third largest family of flowering plants. For a legume to be considered as beans and pulses it shall meet at least the three criteria; to be harvested dry when their seeds are dry and mature, to be specifically grown for their dry seeds as a source of edible protein and fiber, and not used for oil extraction and sowing purposes; as oil being crops and cover crops are not considered as pulses [1]. While all legumes are pulses and beans, not all beans and pulses are legumes. Common beans, chickpeas, and mung beans are both pulses and legumes.. Beans are a type of legume. In short, it can be said that legumes are the umbrella term including all forms of beans and peas that come from the *Fabaceae* or *Leguminosae* botanical family [2]. This family include thousands of varieties that are grown around the world, with the main type of dry and fresh beans, dry and fresh peas, lentils, chickpeas, and peanuts. Beans are also classified as pulses [3].

Due to their nutritional value and culinary versatility, kidney beans or red beans, also called as common beans (*Phaseolus Vulgaris L*) are widely consumed globally. It has a long history of cultivation and consumption dating back thousands of years. Kidney beans are cultivated in various regions and are accessible to a wide range of the population. In Pakistan, kidney beans are grown mostly in the maize crop agroclimatic environments. The local farmers use the conventional method of the previous harvest as a planting seed, which is usually adapted to local climates. It is cultivated on 141,000 hectares with an estimated 93 thousands tons production in 2012. Due to its good quality and higher productivity is considered a promising crop [4-6].

The white beans *(Vigna unguiculata),* also known as black eyed beans or cow peas, is a subspecies is locally known as white lobia is a multipurpose crop but has not been given much priority as compared to other beans. This exotic bean is either imported or cultivated by some local farmers [7]. Mung bean *(Vigna radiata*) is one of the most important kharif crops and pulses in Pakistan, primarily grown in Southern Punjab and Sindh. Approximately 80% of the mung bean production comes from Punjab, allowing Pakistan to become self-sufficient in its mung bean cultivation.[8]. Similarly, chickpea *(Cicer Arietinum L.),* also known as "Garbanzo bean," "Bengal gram," or "Kabuli Channa," is a vital annual pulse crop that belongs to the Cicer genus (Family: Leguminosae, Fabaceae). It serves as a major source of dietary protein in Pakistan and is mainly cultivated through rain-fed agricultural systems. Chickpeas are grown on around 2.2 million hectares, with more than 80% of the production located in the Thal region. Unfortunately, due to a growing population and decreased domestic production, Pakistan is now reliant on imports of chickpeas from other countries [8-10].

Beans are widely recognized as nutritious food ingredients that are high in protein, vitamins, minerals, and phytonutrients.[11]. he common bean variety ‘American Black’ (Phaseolus vulgaris), cultivated in Mexico, contains 20.4 grams of protein, 23.4 grams of total dietary fiber, and 3.6 grams of lipids per 100 grams of dry sample. In comparison, the scarlet runner bean variety ‘Purple Scarlet Runner’ (Phaseolus coccineus) has 18.0 grams of protein, 21.8 grams of total dietary fiber, and 2.8 grams of lipids per 100 grams of dry sample.[12]. Dry beans are said to be a fine source of nitrogen and protein (20– 30%). One portion (90 g or a ½ cup of cooked beans) provides 7 to 8 g of protein, nearly 15% of the recommended dietary intake of protein for a 70 kg adult [13, 14]. Sulfur-containing amino acids are the most limiting [15]. Values for histidine, isoleucine, lysine, phenylalanine, threonine, and valine vary slightly between species and arginine can be detected in some variations. The wild species show higher levels of amino acids than domesticated crops [16]. The digestibility of bean proteins is about 79%; the amino acid score is 0.78 and protein digestibility is between 0.57–0.68 [17]. Beans mostly contain carbohydrates (55–65% on dry weight). The primary components of beans include polysaccharide derivatives and non-derivatives of starch, which is commonly known as dietary fiber. Additionally, they contain small but significant amounts of mono-, di-, and oligosaccharides. Beans are rich in slow-digesting carbohydrates and have a high proportion of non-digestible carbohydrates that can be fermented in the large intestine. The non-digested carbohydrates that reach the colon consist of resistant starch, both soluble and insoluble dietary fiber, and non-digestible oligosaccharides [18-20]. Calcium, magnesium, and potassium are the primary cations found in common beans, with calcium being more readily available than magnesium or potassium. The average mineral concentrations in beans are as follows: copper (18 mg/kg), iron (60 mg/kg), manganese (23 mg/kg), zinc (29 mg/kg), and sulfur (234 mg/kg), with higher levels typically found in wild genotypes. [21]. Beans generally have a low glycemic index (GI) compared to other carbohydrate-rich foods, which is likely due to their resistant starch and fiber content. The GI of beans ranges from 29 to 38, whereas brown rice has a GI of 50 and rolled oats have a GI of 55.for rolled oats [22]. The low glycemic index (GI) of beans can offer significant health benefits. For instance, a study involving participants with diabetes found that those who increased their legume intake by at least one cup per day experienced a decrease in glycated hemoglobin (Hb A1c) values of 0.5%. In contrast, participants who supplemented with wheat fiber only saw a decrease of 0.3%. The difference between these two treatments was statistically significant ($P < 0.001$) [23]. It's important to note that even a change in Hb A1c levels of just 1% can lead to a 15–18% reduction in the risk of ischemic heart disease (IHD) among individuals with diabetes. [24].

Beans are rich in various polyphenolic compounds, including tannins, phenolic acids, and flavonoids, which may offer a range of health benefits. Many of these polyphenols are known for their strong antioxidant properties. Notably, a study examining 25 different types of beans found that the total antioxidant activity of the beans was directly related to their polyphenol content [24, 25]. Besides nutritive values, legumes are also a source of phenolics, especially isoflavones. A review by Singh et al. (2017) summarized the phenolic content of various beans and their relationship to antioxidant activities. The beans were categorized into dry beans, lentils, chickpeas, cowpeas, pigeon peas, and green peas. Among all the data reported, dry beans were the most extensively studied, showing a wide range of total phenolic content. This ranged from 0.25 mg of gallic acid equivalent (GAE) per gram of dry weight (DW) in

kidney beans to 157.6 mg GAE/g DW in fava beans. Additionally, the antioxidant activities varied based on both internal factors, such as the different varieties of beans, and external factors, including the methods of extraction and the techniques used to measure antioxidant activity.[26].

Beans contain several compounds that have traditionally been classified as antinutrients, which can interfere with the digestion and absorption of nutrients. These include protease inhibitors, lectins, phytates, and oxalates [27, 28]. However, it's important to note that the effects of these individual components, when studied in isolation, may not accurately predict their effects when consumed together in a typical diet. [29]. The phytate content of beans ranges from ~0.1% to 2% [30, 31]. Phytate is not destroyed by heat, so it is an important factor affecting mineral absorption from beans, especially for minerals such as zinc, which tends to be low in plant-based diets. Soaking and fermentation may reduce the effects of phytate and increase zinc absorption [32]. Phytate reduces the absorption of iron from beans and other plant foods, which is one reason why the Recommended Dietary Allowance (RDA) for iron is 1.8 times higher for vegetarians than for non-vegetarians. Additionally, beans contain variable amounts of iron, primarily in the storage form called ferritin. For instance, in white beans, as much as 90% of the total iron is found in the form of ferritin or other soluble iron.[33]. Ferritin may be resistant to traditional inhibitors of iron absorption and therefore much better absorbed than generally thought [34]. Findings are conflicting because it is unclear how much ferritin survives cooking and digestion.[35]. Phytate is an example of an antinutrient that may exert beneficial effects. It is an antioxidant [36] that may reduce the risk of certain cancers [37] and kidney stones [38].

Phytates [chemically known as myoinositol (1,2,3,4,5,6) hexakisphosphate] is found in numerous plants and their parts, including seeds, nuts, legumes, and cereals [39]. Phytate is also called inositol hexakisphosphate (IP6, InsP6) or phytic acid, with the last one commonly used. Phytates found in plants serve as a source of energy and possess antioxidant properties by donating phosphate groups. However, their primary function is as storage agents for minerals, particularly by chelating copper (Cu^{2+}) and zinc (Zn^{2+}) cations. This chelation is facilitated by the presence of negative charges at physiological pH [40]. Given the deleterious effects of phytic acid, it is necessary to reduce phytic acid before consumption to improve the nutritional quality of the dry beans. It has been observed by earlier workers that soaking in water reduced the amount of phytic acid in the beans to some extent. Reduction in phytic acid content of some edible legumes during germination and cooking has also been reported in the literature. This paper reports the effect of different soaking and cooking methods on the phytic acid content and mineral digestibility of four commonly consumed dietary beans in Pakistan.

MATERIALS AND METHODS

Sampling

The sample comprised of legumes i-e, Red Kidney Beans ((*Phaseolus Vulgaris L*), White Kidney Beans ((*Vigna unguiculata)*, Mung Beans *(Vigna radiata)* & Chick Peas *(Cicer Arietinum L.),* were procured from the agricultural fields of the Nuclear Institute of Food & Agriculture, Peshawar, and the Ayub Agricultural Institute, Faisalabad.

Preparation of the Samples

The samples were cleaned of impurities. The unsoaked samples were ground in a stainless grinder to pass through a standard 40-mesh screen. The ground samples were placed in an airtight plastic bottle placed in desiccators and stored at 4°C from which the required quantities were taken for chemical determinations (analysis).

Sample Preparation

The samples were divided into eight categories based on the preparatory and cooking methods applied to them. These categories were Raw, 1-hour soaking, 6-hour soaking, overnight soaking, boiling until the whole water is absorbed, boiling until the sample is tender, Pressure cooking with soda, and Pressure cooking without soda. The samples in the first category were kept raw (controlled) for ease of comparison. Four types of pulses were selected, and eight processing methods were applied.

Types of Samples

Raw Beans

The raw seeds were mixed thoroughly, and 12 samples were used to determine phytic acid content in raw seeds in triplicate. The beans were ground before phytic acid determination. The grinding was done with a mechanical grinder.

1- Hour -Soaked Beans

The seeds of the respective beans were soaked by submerging them in tap water in a container for one hour. The excess water was removed with the help of a sieve, and then the adherent moisture was removed by gently rolling them on thick absorbent cloth. Afterwards, sieved samples were placed in an oven to evaporate the excess moisture at 70 degrees Celsius. After drying, the samples were then subjected to chemical analyses.

6- 6-Hour-Soaked Beans

As the study is based on preparatory and cooking methods used commonly in Pakistan, all the beans were soaked for six (6) hours, which is also a common pre-cooking procedure in Pakistani cooking practices. The beans were soaked for six (6) hours, and excess water

was drained through a sieve and then placed in an oven to remove the excess moisture. After drying, the samples were ground with the help of an electric grinder. The samples were then subjected to different lab analyses.

Overnight Soaking

Another common practice in Pakistani households is the overnight steeping of pulses. All the beans were soaked overnight in tap water, sieved in the morning, oven dried, and subjected to laboratory analyses.

Boiling Until the water Absorbed

Boiling is the most common cooking method in Pakistan. The samples were boiled at and above 100°C until the sample was tender and the water was completely absorbed. The samples were then placed in an oven to remove the excess moisture. After drying, the samples were ground with the help of an electric grinder and stored in air-tight jars for analysis.

Boiling till Tender

Boiling in sufficient water is also another common practice, so the samples were boiled in boiling water at 100°C until tender. Afterwards, the excess water was removed by sieving and the samples were then oven-dried, ground, kept in air-tight jars, and tested for different parameters.

Pressure Cooking with Bicarbonate Soda

Beans were pressure-cooked by adding a pinch of bicarbonate soda to the water. The excess water was drained, and the samples were placed in an oven until a static weight. After drying, the samples were ground, stored, and analyzed.

Pressure Cooking Without Bicarbonate Soda

Beans were then pressure-cooked for the prescribed time for each bean. The cooled samples were drained in a sieve and oven-dried for laboratory analyses

Quantification of Phytic Acid

Phytic acid content was quantified using the spectrophotometric method of Haug and Lantzsch [41]. The decrease in iron content (determined calorimetrically with 2, 2′-bipyridine) in the supernatant was measured. Ferric (III) chloride solution (1 mL) was added to 0.5 mL extract. The solution was heated for 30 min in a boiling water bath. After being cooled to room temperature, the solution was centrifuged for 30 min at 4500 rpm. Then, 1 mL of the supernatant was transferred to another test tube and mixed with 1.5 mL of 2, 2′-bipyridine (0.1 g 2, 2′-bipyridine dissolved in 1 mL of thioglycolic acid and the volume was made to 100 mL with distilled water. The absorbance of the reaction mixture was measured at 519 nm against distilled water. The method was calibrated with standard phytic acid solutions for each set of analysis and expressed as mg of phytic acid equivalent/g of sample. The amount of ferric ions precipitated the quantity of phytic acid P was obtained by the standard graph. Phytic acid concentration was quantified by **Minerals Analysis**

Wet Digestion for Phosphorus Analysis

Wet digestion of organic samples is carried out according to the method of AOAC standard methods [42]. Ground the sample (0.25g) was placed in 50ml Erlenmeyer flasks, add nitric acid (ml) and are placed on hot plate at 70°C until particles disappear. The temperature is raised slowly to 140°C and most of the nitric acid is allowed to evaporate. The flask is then allowed to cool and 3ml of Acid mixture (1:1 nitric and Perchloric acid) is added, and the temperature is raised until dense white fumes of perchloric acid appear (about 200°C). The mixture was then cooled down and the volume was made up to 50.0 ml by adding distilled water in a volumetric flask and was labeled.

Determination of Phosphorus Content

Phosphorus was determined colorimetrically using the vanadate molybdate method of Hasan as per the AOAC method [42]. About 0.2N HCl, Trichloroacetic acid 30% w/v, H_2SO_4 1N, Ascorbic acid 10% w/v, Ammonium molybdate 0.42% w/v. **Barton's Reagent** was prepared by taking 25 mg of ammonium molybdate in 400 ml distilled water. 1.5 g of ammonium metavanadate was dissolved into 200 ml of boiling water and cooled. Then, 250 ml (65%) concentrated nitric acid was added to meta vanadate solution. Molybdate solution was poured into the vanadate solution and the volume was made to 1000 ml with distilled water. For Standard Phosphorus Solution 500 ppm solution of phosphorus 500 ppm was prepared by dissolving 2.1111958 of K_2HPO_4 into distilled water and the volume was made to 1000 ml. From the stock solution, a series of solutions were prepared to contain 1, to 100 ppm of phosphorus. Colour was developed by adding a few drops of NH_3, a few drops of [NO_3], HOCl (1:1) mixture and 12.5 ml of Bartons reagent. The volume was made to 50 ml with distilled water and absorbance was read at 470 nm against blank. A curve was drawn from the results. Wet digested samples, 5 ml, was added to a 50 ml volumetric flask. A few drops of NH_3, HOCl mixture, and 12.5 ml of Bartons reagent was added to it, and the volume was made with distilled water. The absorbance was noted after 10 minutes at 470 nm against a blank, and the amount of phosphorus in the sample was determined using the standard curve. For **Extraction 25, 35 – 60** mg samples were placed into screw-capped test tubes. Ten milliliters of 0.2 N HCl was added, and the tubes were shaken at room temperature for 3.5 h. The tubes were then centrifuged at 3,900g for 15 min. Alternatively, the contents were let stand for 20 min. Supernatants were transferred into fresh tubes and used for Pi determinations. For the **Determination of** Pi, 2 ml of each extract was placed into test tubes. One l of 30% (w/v) aqueous trichloroacetic acid was added to each sample. The plates were shaken and centrifuged at 3,900g for 10 min. One ml of each supernatant was transferred into a fresh stoppered tube. Two ml of 0.42%

(w/v) ammonium molybdate-1 N H_2SO_4:10% (w/v) ascorbic acid (7:1) was added. The tubes were incubated at 37°C for 30 min. A_{800} was measured. Potassium phosphate was used as a standard. Pi content is presented as Pi phosphorus. Phosphorus concentrations were determined through the following formulae

Molecular weight of phytic acid ($C_6H_{18}O_{24}P_6$) = 660 12Na atoms replace 12-H atoms. So, 12 x 23 = 27612 (H) = 264.So, the molecular weight of sodium phytate = 660 + 264 = 924g.Now there were 6 phosphorus atoms in sodium phytate. P = 31 x 6 = 186.So, 924 of Na-phytate contains 186 grams of phosphorus.0.15g of Na phytate contains 186/925 x 0.15 = 0.0302g/100ml.Or 30.2mg/100ml or 0.302mg/100ml or 302µg/ml. The concentration of phosphorus in 0.15g/100 ml of Na phytate solution was 302mg/ml.

Dry Digestion for Iron Analysis

The AACC method was used to determines iron by the reaction with Ortho-phenanthroline and spectrophotometric measurement was used to determine the iron content in the samples [43]. Accurately weighed 2 to 10g of sample (depending on concentration of iron excepted) into a clean crucible. Char on a hot plate. Ash overnight in a muffle furnace at <550°C. The crucible was removed from furnace and cool to room temperature. About 5 ml concentrated HCl, letting acid rinse the upper portion of the crucible. After evaporation, 2 ml concentrated HCl was added and was covered with a watch glass, was heated for 5 min and then rinsed with water. It was filtered and volume was made quantitatively into a 25 ml volumetric flask to dilute and was mixed thoroughly. Pipette about 10 ml aliquot into a 25 ml volumetric flask and 01 ml Hydroxylamine-HCl solution was added and mixed thoroughly. After 5 minutes 5 ml buffer solution and 1 ml Ortho-phenanthroline solution were added and was left to stand for 30 min. The absorbance of the sample was measured against standard and blank solution in a spectrophotometer at 510 nm.

Calculation of Mineral Solubility

The mineral solubility is calculated as the percentage of soluble minerals relative to the total minerals in the sample.

Statistical Analysis

Data was statistically analyzed through IBM SPSS version 19**.** Data was analyzed for mean, standard deviation. A paired sample t-test was used to test the significance of the differences in phytate contents in the raw and dry heat-cooked samples

RESULTS AND DISCUSSION

Effects of Various Processing on Phytate contents in Red Kidney Beans *(Phaseolus Vulgaris*) The impact of various processing methods on phytic acid degradation in red kidney beans (Table 1) revealed significant variations. Soaking for 6 hours resulted in the highest phytic acid reduction, with a 33.0% degradation (0.65 ± 0.65), demonstrating its effectiveness in enhancing mineral bioavailability. Interestingly, extending the soaking period to 12 hours led to a minimal degradation of 3.1% (0.94 ± 0.95), suggesting a possible equilibrium effect. Boiling till tenderized unexpectedly showed a slight increase in phytic acid levels (4.1%, 1.01 ± 1.02), while boiling until moisture content was absorbed had a negligible reduction (2.1%, 0.69 ± 0.71). Pressure cooking with soda proved to be an effective method, reducing phytic acid by 19.6% (0.78 ± 0.80), whereas pressure cooking without soda had a lower degradation rate of 6.2% (0.65 ± 0.66), indicating that alkalinity enhances phytic acid breakdown. One-hour soaking resulted in a moderate 22.7% reduction (0.75 ± 0.77), while the raw red kidney beans maintained their original phytic acid levels (0.97 ± 0.98, 0% degradation). Overall, 6-hour soaking emerged as the most efficient processing method, followed by pressure cooking with soda, while boiling and prolonged soaking beyond 6 hours were less effective. These findings emphasize the importance of optimizing processing techniques to improve the nutritional quality of legumes as suggested by other authors [44].

Table 1 Red Kidney Beans *(Phaseolus Vulgaris*) Phytic acid content & % Degradation

S. No	Processing Methods	Mean % ± SD	% Degradation
1	Raw red kidney beans	0.97 ± 0.98	0%
2	1-hour-soaked red kidney beans	0.75 ± 0.77	22.7%
3	6-hour-soaked red kidney beans	0.65 ± 0.65	33.0%
4	12-hour-soaked red kidney beans	0.94 ± 0.95	3.1%
5	Boiling till tenderized red kidney beans	1.01 ± 1.02	4.1%
6	Boiling till the moisture content was absorbed,	0.69 ± 0.71	2.1%
7	Pressure cooked with soda	0.78 ± 0.80	19.6%
8	Pressure cooked without soda	0.65 ± 0.66	6.2%

Effects of Various Processing on Phytate contents in White beans *(Vicia Faba*)

The impact of various processing methods on the degradation of phytic acid in white beans (Table 2) showed significant differences. Raw white beans contained the highest level of phytic acid at 1.096 ± 0.03%, serving as the baseline with 0% degradation. Among the soaking treatments, soaking for 1 hour reduced the phytic acid content to 0.72 ± 0.01%, resulting in a 34.1% degradation. Soaking for 6 hours further decreased the phytic acid level to 0.63 ± 0.05%, achieving a 42.9% degradation. The most effective

method was soaking for 12 hours, which lowered the phytic acid content to 0.54 ± 0.38% and led to a 50.7% degradation—the highest reduction observed across all treatments. Boiling methods also proved effective in reducing phytic acid. Boiling the beans until tender reduced the phytic acid to 0.60 ± 0.01%, achieving a 45.3% degradation. However, boiling until the moisture was fully absorbed was much less effective, with the phytic acid content remaining at 0.89 ± 0.01%, corresponding to only an 18.4% degradation. Pressure cooking methods varied in effectiveness as well. Pressure cooking with soda resulted in a phytic acid content of 0.89 ± 0.09%, leading to an 18.6% degradation. In contrast, pressure cooking without soda was slightly more effective, reducing phytic acid to 0.80 ± 0.00% and achieving a 27.2% degradation. Overall, the most effective method was soaking for 12 hours, followed by boiling until tender, which reduced phytic acid by nearly half (45.3%). Pressure cooking without soda demonstrated better effectiveness (27.2% degradation) compared to cooking with soda (18.6% degradation), indicating that soda did not enhance phytic acid breakdown in white beans. On the other hand, boiling until moisture absorption (18.4% degradation) and pressure cooking with soda (18.6% degradation) were the least effective methods. These findings underscore the importance of extended soaking or boiling until tender, as suggested by others, to maximize phytic acid reduction in beans, potentially improving mineral bioavailability and the nutritional quality of the beans [44,45].

Table 2: White beans *(Vicia Faba*) Phytic acid content & % degradation Effects of Various Processing on Phytate contents in mung beans *(Vigna Radiatae)*

S. No	Processing Method	Mean % ± SD	% Degradation
1	Raw white beans	1.096 ± 0.03	0%
2	1-hour-soaked white beans	0.72 ± 0.01	34.1%
3	6-hour -soaked white beans	0.63 ± 0.05	42.9%
4	12-hour -soaked white beans	0.54 ± 0.38	50.7%
5	Boiling till tenderized white beans	0.60 ± 0.01	45.3%
6	White beans boiled till whole moisture content was absorbed	0.89 ± 0.01	18.4%
7	White beans pressure cooked with soda	0.89 ± 0.09	18.6%
8	White beans pressure cooked without soda	0.80 ± 0.00	27.2%

The effect of different processing methods on phytic acid degradation in mung beans (Table 3) revealed significant reductions across most treatments. The raw mung beans had the highest phytic acid content (2.08 ± 0.01%), serving as the baseline with 0% degradation. Among the soaking treatments, 1-hour soaking substantially reduced phytic acid levels to 0.66 ± 0.00%, achieving an impressive 68.3% degradation. The 12-hour soaking method further reduced phytic acid to 0.63 ± 0.02%, showing the highest reduction at 69.7%. However, an unusual negative value was observed for 6-hour soaking (-0.02 ± 0.00%), indicating an unexpected increase in phytic acid levels by 101%, possibly due to enzymatic or microbial activity affecting phytic acid content.Boiling methods also played a crucial role in phytic acid reduction. Boiling until tenderized led to a decrease in phytic acid content to 0.85 ± 0.02%, achieving a 59.1% degradation, while boiling until moisture was fully absorbed showed a similar trend, with phytic acid levels at 0.87 ± 0.01%, resulting in a 58.2% degradation. Pressure cooking was moderately effective, with pressure cooking with soda reducing phytic acid to 0.94 ± 0.03%, yielding a 50.0% degradation. Interestingly, pressure cooking without soda performed better, reducing phytic acid to 0.82 ± 0.00%, achieving a 60.6% degradation, suggesting that soda was not essential for enhanced reduction in mung beans.Overall, 12-hour soaking proved to be the most effective method, with 69.7% degradation, followed closely by 1-hour soaking (68.3%). Boiling until tenderized (59.1%) and pressure cooking without soda (60.6%) also demonstrated significant reductions. The negative degradation in 6-hour soaking (-101%) indicates an anomaly that requires further investigation. These results suggest that soaking mung beans for 1 to 12 hours is the most efficient way to reduce phytic acid, thereby enhancing the bioavailability of essential minerals. The results of phtate degradation in the current study align with another study which reported overnight soaking and boiling reduce the antinutrients substantially [45, 46].

Table: 3 Phytic acid Content & % Degradation in mung beans *(Vigna Radiatae)*

S.No	Processing Method	Mean % ± SD	% Degradation
1	Raw mung beans	2.08 ± 0.01	0%
2	1-hour-soaked mung beans	0.66 ± 0.00	68.3%
3	6-hour-soaked mung beans	-0.02 ± 0.00	-101.0%
4	12-hour-soaked mung beans	0.63 ± 0.02	69.7%
5	Boiling till tenderized mung beans	0.85 ± 0.02	59.1%
6	Mung beans boiled till moisture content was absorbed	0.87 ± 0.01	58.2%
7	Mung beans pressure cooked with soda	0.94 ± 0.03	50.0%
8	Mung beans pressure cooked without soda	0.82 ± 0.00	60.6%

Effects of Various Processing on Phytate contents in

chick peas *(Cicer Arietinum)*

The effect of different processing methods on phytic acid degradation in chickpeas (Table 4) was relatively minimal across all treatments. The raw chickpeas had an initial phytic acid content of 0.70 ± 0.01%, serving as the baseline (0.0% degradation). Soaking methods had little impact, with 1-hour soaking unexpectedly increasing phytic acid to 0.74 ± 0.00%, resulting in a 5.71% rise instead of degradation. Both 6-hour and 12-hour soaking showed negligible reductions, lowering phytic acid to 0.69 ± 0.01%, with a 1.43% degradation in both cases. Boiling methods were more effective than soaking. Boiling until tenderized reduced phytic acid to 0.61 ± 0.01%, achieving a 12.86% degradation, while boiling until moisture was absorbed showed a more modest reduction, lowering phytic acid to 0.66 ± 0.08% (5.71% degradation). Pressure cooking proved to be the most efficient method. Pressure cooking with soda reduced phytic acid to 0.63 ± 0.05%, yielding a 10.00% degradation, whereas pressure cooking without soda was the most effective, lowering phytic acid to 0.58 ± 0.05%, achieving a 17.14% degradation. Overall, pressure cooking without soda (17.14%) and boiling until tenderized (12.86%) were the most effective methods for reducing phytic acid, while soaking had minimal impact, with 6-hour and 12-hour soaking reducing phytic acid by only 1.43%. Interestingly, 1-hour soaking led to a slight increase in phytic acid, which may be due to enzymatic activity or variations in experimental conditions. These results indicate that heat-based processing methods, particularly pressure cooking and boiling, are necessary for significant phytic acid degradation in chickpeas, while soaking alone is insufficient to reduce anti-nutritional factors effectively. These findings are in agreement with the findings of another such study [47]

Table: 4 Phytic acid content & % degradation in chick peas *(Cicer Arietinum)*

S.No	Processing Method	Mean % ± SD	% Degradation
1	Raw chickpeas	0.70 ± 0.01	0.0%
2	1-hour soaking chickpeas	0.74 ± 0.00	5.71%
3	6-hour soaking chickpeas	0.69 ± 0.01	1.43%
4	12-hour soaking chickpeas	0.69 ± 0.01	1.43%
5	Boiling till tenderized chickpeas	0.61 ± 0.01	12.86%
6	Boiling till moisture content was absorbed chickpeas	0.66 ± 0.08	5.71%
7	Pressure cooking with soda chickpeas	0.63 ± 0.05	10.00%
8	Pressure cooking without soda chickpeas	0.58 ± 0.05	17.14%

Mean Effects of Processing on Phytate Degradation

The mean effects of different domestic processing on the phytate contents of beans are given in Figure 1-6. Soaking pulses for 1 hour resulted in varying degrees of phytic acid (P.A) degradation among different types. Mung beans experienced the highest reduction at 68.3%, followed by white beans at 34.1%, red kidney beans at 22.7%, and chickpeas at just 5.71%. Mung beans had an initial phytic acid content of 2.08%, which significantly decreased to 0.66% after 1 hour of soaking, indicating their strong response to short-duration soaking. In contrast, white beans started with 1.096% phytic acid and showed a 34.1% reduction, dropping to approximately 0.72%. This demonstrates that soaking can moderately reduce anti-nutritional factors. Red kidney beans, with an initial phytic acid level of 0.97%, exhibited a 22.7% reduction, lowering their content to 0.75%. While this suggests that short soaking can decrease phytic acid levels, additional methods such as prolonged soaking or boiling may be necessary for a more significant reduction. Chickpeas displayed the least reduction, with a mere 5.71%, having phytic acid levels remain nearly unchanged from 0.70% in their raw state to 0.74% after soaking, indicating that 1 hour of soaking is ineffective for reducing phytic acid in chickpeas. Longer soaking or alternative techniques, such as boiling or pressure cooking, may be required to break down their anti-nutritional compounds. When pulses were soaked for 6 hours, the results varied significantly. White beans again showed the highest reduction at 42.9%, lowering the phytic acid content from 1.096% to 0.63%. This substantial decrease indicates that extended soaking is highly effective in breaking down anti-nutritional factors in white beans. Similarly, red kidney beans had a notable reduction of 33%, dropping their phytic acid from 0.97% to 0.65%, reinforcing the effectiveness of prolonged soaking. On the other hand, chickpeas only exhibited a minimal phytic acid reduction of 1.43%, with levels remaining nearly unchanged at 0.69% after 6 hours of soaking. This suggests that even extended soaking is not an effective strategy for reducing phytic acid in chickpeas, and additional processing methods may be necessary for significant reduction. An unexpected finding was observed with mung beans, where the phytic acid content dropped to -0.02%, resulting in an anomalous degradation value of -101%. This extreme result raises questions about measurement inconsistencies, enzymatic activity, or microbial action affecting the phytic acid content. Such a dramatic reduction is not typical, necessitating further investigation to validate these findings and identify possible experimental errors or biochemical interactions. Overall, white beans and red kidney beans benefited most from 6-hour soaking, while chickpeas showed resistance to phytic acid breakdown. The anomalous results for mung beans highlight the need for further research to confirm the accuracy of phytic acid measurements in this pulse. These findings emphasize

that soaking effectiveness varies among different pulses and that some legumes may require additional processing techniques to maximize phytic acid degradation and enhance mineral bioavailability. Soaking pulses for 12 hours resulted in further significant variations in phytic acid degradation. Mung beans showed the highest reduction at 69.7%, lowering their phytic acid content from 2.08% to 0.63%. This suggests that prolonged soaking is highly effective for breaking down phytic acid in mung beans, making them the most responsive to this method. White beans also displayed a substantial reduction of 50.7%, with levels decreasing from 1.096% to 0.54%, indicating effective reduction of anti-nutritional factors. In contrast, red kidney beans showed minimal degradation at only 3.1%, maintaining a high phytic acid content of 0.94%. This suggests that soaking alone is not an efficient method for reducing phytic acid in kidney beans. Likewise, chickpeas exhibited the lowest reduction, with only a 1.43% decrease, resulting in a phytic acid level of 0.69%, which is nearly unchanged from their raw state. This confirms that soaking alone, even for extended periods, is ineffective for chickpeas, and additional treatments such as boiling or pressure cooking may be necessary for significant phytic acid breakdown. Overall, mung beans and white beans demonstrated the highest reductions in phytic acid, indicating that extended soaking is highly beneficial for these pulses. However, red kidney beans and chickpeas retained most of their phytic acid, highlighting the need for alternative processing techniques beyond soaking to enhance mineral bioavailability and effectively reduce anti-nutritional factors. Boiling pulses until tender lead to varying degrees of phytic acid degradation, with mung beans showing the highest reduction at 59.1%, lowering their phytic acid content from 2.08% to 0.85%. The percent phytic acid and percent phytate reduction are similar to other studies [44-47].

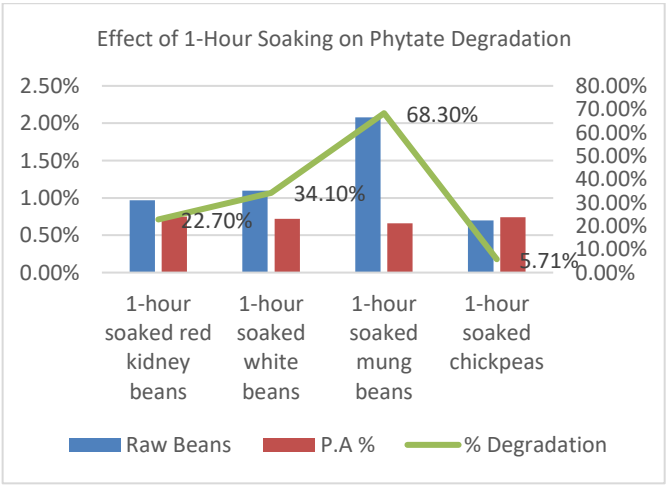

Figure 1:Effect of 1-Hour Soaking on Phytate Degradation in Beans

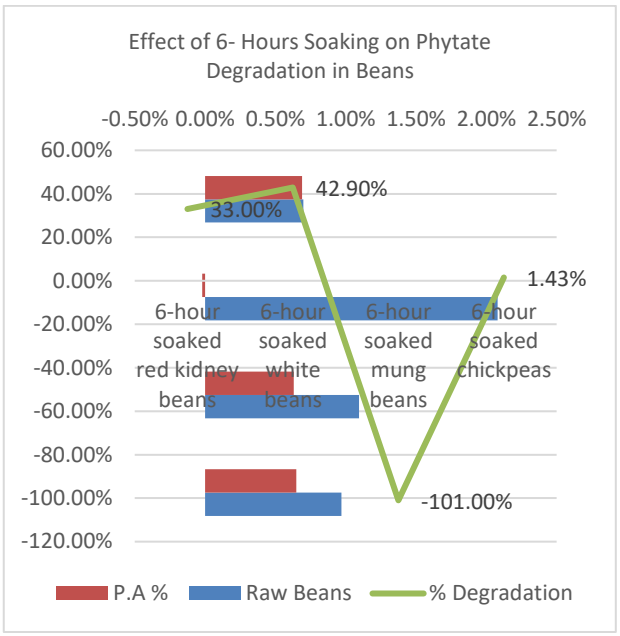

Figure 2: Effect of 6- Hours Soaking on Phytate Degradation in Beans

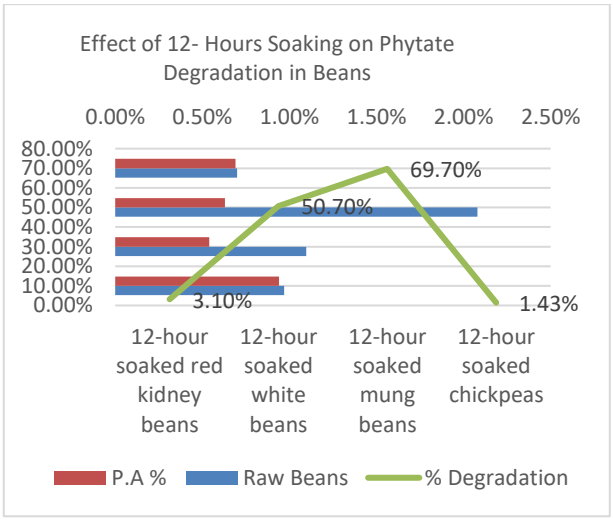

Figure 3: Effect of 12- Hours Soaking on Phytate Degradation in Beans

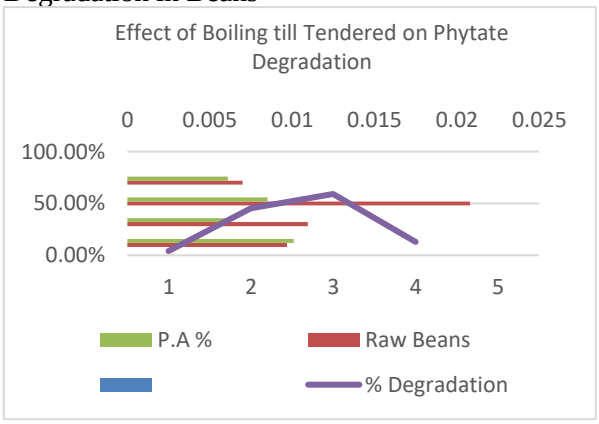

Figure 4: Effect of Boiling till Tendered on Phytate Degradation

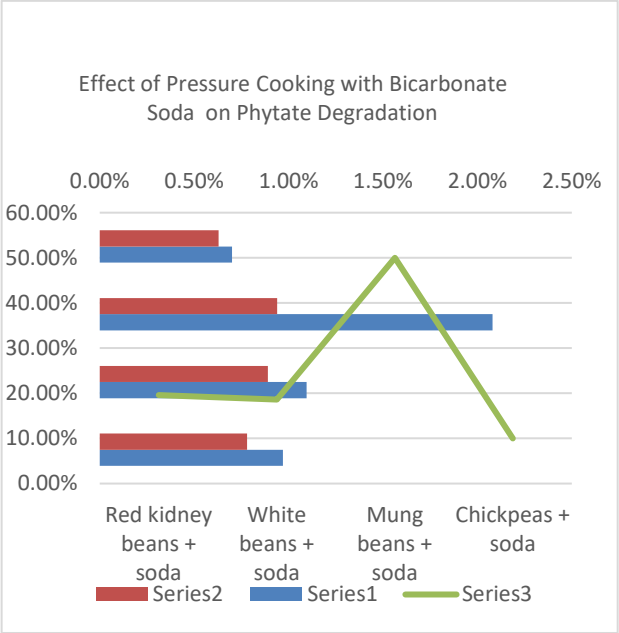

Figure 5: Effect of Pressure Cooking with Bicarbonate Soda on Phytate Degradation

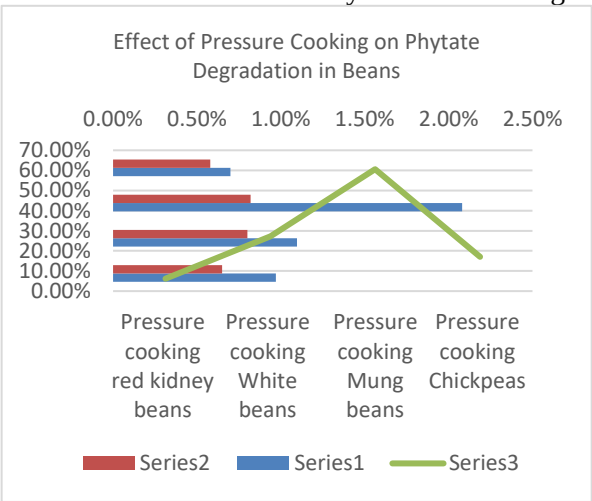

Figure 6: Effect of Pressure Cooking on Phytate Degradation in Beans

Mineral Content (Phosphorus & Iron) in Legumes The phosphorus (P) and iron (Fe) content in legumes (Table 5) varied significantly across different processing methods, demonstrating the impact of cooking on mineral retention. Among raw legumes, chickpeas had the highest iron content (166±0.06), while red kidney beans contained the highest phosphorus levels (5123±0.06). In contrast, white beans had the lowest mineral content, with 3593 ±0.02 of phosphorus and just 13±0.161of iron. Processing influenced these values differently, with boiling until tenderized leading to phosphorus losses in all legumes, as red kidney beans dropped to 4501±0.002(a 12.1% loss), and chickpeas decreased to 3638±0.004 (a 13.8% loss). However, boiling increased iron availability, with red kidney beans rising to 38±0.02 (a 58.3% increase) and white beans to 19±0.051(a 46.2% increase), whereas chickpeas experienced a slight reduction to 160±01.64(a 3.6% loss). Pressure cooking without soda had mixed effects on mineral retention. In red kidney beans, phosphorus levels increased significantly to 5683±1.02, possibly due to moisture loss concentrating the mineral content, while iron content only increased to 32±0.95, lower than the 38 PPM observed in boiled beans. White beans showed a modest phosphorus increase to 3791 PPM, but iron remained unchanged at 13±0.53, suggesting minimal impact on iron retention. Chickpeas retained their phosphorus content better (increasing to 3887±0.15), while iron levels remained stable at 161±0.61, indicating that chickpeas naturally retain iron during cooking, regardless of the method used. Overall, boiling was more effective at enhancing iron availability, particularly in red kidney beans and white beans, while pressure cooking without soda helped retain more phosphorus. These results highlight that different cooking methods impact mineral retention in legumes, and selecting the appropriate technique is crucial to maximizing nutrient bioavailability. The mineral content of the current study aligns well with another similar study [48].

Table 5: Mineral Content (Phosphorus & Iron) in Legumes

S.No	Sample	P (Phosphorus) PPM	Fe (Iron) PPM
1	Raw red kidney beans	5123± 0.06	24±0.19
2	Raw white beans	3593 ±0.02	13±0.161
3	Raw chickpeas	4222±0.01	166±0.06
4	Red kidney beans tenderized	4501±0.002	38±0.02
5	White beans tenderized	4246 ±0.03	19±0.051
6	Chickpeas tenderized	3638±0.004	160±01.64
7	Red kidney beans without soda	5683±1.02	32±0.95
8	White beans without soda	3791±0.03	13±0.53
9	Chickpeas without soda	3887±0.15	161±0.61

Effect of various processing on mineral solubility The phosphorus (P) and iron (Fe) solubility in legumes (Table 6) varied significantly across different processing methods, indicating notable changes in mineral availability. Among raw legumes, white beans exhibited the highest phosphorus solubility (43.4%) and an exceptionally high iron solubility (196.5%), followed by chickpeas (36.6% phosphorus, 45.8% iron) and red kidney beans (29.7% phosphorus, 26.4% iron). Cooking influenced these values differently, with boiling until

tenderized improving phosphorus solubility across all legumes, increasing to 35.2% in red kidney beans, 37.4% in white beans, and 39.5% in chickpeas. However, iron solubility showed mixed results, significantly increasing in red kidney beans (68.4%), while white beans dropped to 137.2% and chickpeas declined to 32.1%, suggesting that boiling enhances iron bioavailability in some legumes but reduces it in others. Pressure cooking without soda had varied effects, with phosphorus solubility slightly decreasing in red kidney beans (26.8%) but remaining stable in white beans (43.0%) and chickpeas (39.8%). In contrast, iron solubility increased in red kidney beans (79.4%) but declined sharply in white beans (58.8%) and chickpeas (15.8%), indicating that pressure cooking may improve iron availability in red kidney beans while negatively affecting white beans and chickpeas. Overall, boiling proved to be more effective in enhancing iron solubility in red kidney beans, while pressure cooking without soda helped retain phosphorus but reduced iron solubility in white beans and chickpeas. These findings emphasize that different legumes respond uniquely to various processing techniques, highlighting the need for pulse-specific cooking methods to optimize mineral retention and bioavailability, as reported by other studies [50, 51].

Table 6: Mineral Solubility in Beans

S/N	Sample	P % Sol	Fe % Sol
1	Raw red kidney beans	29.7	26.4
2	Raw white beans	43.4	196.5
3	Raw chick peas	36.6	45.8
4	Red kidney beans tenderized	35.2	68.4
5	White beans tenderized	37.4	137.2
6	Chick peas tenderized	39.5	32.1
7	Red kidney beans without soda	26.8	79.4
8	White beans without soda	43.0	58.8
9	Chick peas without soda	39.8	15.8

CONCLUSION

The current study concludes that soaking and cooking beans, especially boiling them in water, increases the solubility of certain minerals. phosphorus may become more soluble in the cooking water, while iron typically remains in the beans. Soaking beans in water for several hours can reduce phytate levels by up to 30%, as some of the phytate leaches into the soaking water. Cooking beans, particularly when combined with soaking, further decreases phytate content. Different cooking methods can have varying impacts on phytate levels, with pressure cooking being especially effective at reducing phytic acid levels. Phytate binds to minerals like phosphorus and iron, making them less available for absorption in the body. By reducing phytate content, soaking and cooking improve the bioavailability of these and other nutrients.

ACKNOWLEDGEMENTS

The authors acknowledge the assistance of the staff of the Food Science Division, NIFA in the estimation of phytates in the study.

REFERENCES

1. Food & Agriculture Organization of the United Nations.https://www.fao.org/world-pulses-day/en#:~:text=World%20Pulses%20Day%20%7C%2010%20February
2. Alghamdi, S.S. Genetic behavior of some selected faba bean genotypes. African Crop Sci. Conference proceedings. Afr. Crop Sci. Soc. El-Minia, Egypt, 8: 709-714.
3. Alghamdi, S.S.K. and A. Ali. 2004. Performance of several newly bred faba bean lines. Egypt. J. Plant Breed.2007;8:189- https://scholar.google.com/citations?user=BCfSDA4AAAAJandhl=en
4. Anonymous. Project coordinator's Report of AICRP on MULLARP. Indian Institute of Pulses Research, Kanpur,2012.. https://www.arccjournals.com/journal/agricultural-science-digest/D-4172.
5. Pfeiffer, J M., Dun S, Mulawarman B and Rice K J. 2006. Bio-cultural diversity in traditional rice-based agro ecosystems: indigenous research and conservation of mavo (Oryza sativa L.) upland rice landraces of eastern Indonesia. Environ. Dev. 2006; Sustain. https://www.researchgate.net/profile/Kevin_Rice3/publication/226621249_Biocultural_diversity_in_traditional_ricebased_agroecosystems_indigenous_research_and_conservation_of_mavo_(Oryza_sativa_L.)_upland_rice_landraces_of_eastern_Indonesia/links/00b495237524e54b68000000
6. Nisar, M., Ghafoor A Khan M R. Phenotypic Variation in the Agronomic and Morphological Traits of Pisum sativum L. Germplasm obtained from different parts of the World. Russian J. Genet.2011;47(1):19– https://link.springer.com/article/10.1134/S102279541012104X, https://doi.org/10.1134/S102279541012104X
7. Shaukat M S. Crop Production Technology (CPT) of Cowpea (Vigna unguiculata L. Walp.) 2013. https://pakagrifarming.blogspot.com/2013/04/crop-production-technology-cpt-of.html https://aari.punjab.gov.pk/mung_pulses
8. Koul B, Sharma K, Sehgal V, Yadav D, Mishra M, Bharadwaj C. Chickpea (Cicer arietinum L.) Biology and Biotechnology: From Domestication

to Biofortification and Biopharming. Plants (Basel). 2022 Oct;11(21):2926.:10.3390/plants11212926. https://aari.punjab.gov.pk/chickepea_kabuli_pulses
9. Geraldo R., Santos C.S., Pinto E., Vasconcelos M.W. Widening the Perspectives for Legume Consumption: The Case of Bioactive Non-nutrients. Front. Plant Sci. 2022; 13:2054. doi: 10.3389/fpls.2022.772054.
10. Corzo-Ríos L.J., Sánchez-Chino X.M., Cardador-Martínez A., Martínez-Herrera J., Jiménez-Martínez C. Effect of cooking on nutritional and non-nutritional compounds in two species of Phaseolus (P. vulgaris and P. coccineus) cultivated in Mexico. Int. J. Gastron. Food Sci. 2020; 20:100206. doi: 10.1016/j.ijgfs.2020.100206.
11. Singh B., Singh J.P., Shevkani K., Singh N., Kaur A. Bioactive constituents in pulses and their health benefits. J. Food Sci. Technol. 2017; 54:858 870. doi: 10.1007/s13197-016-2391-9.
12. Chaieb N., González J.L., López-Mesas M., Bouslama M., Valiente M. Polyphenols content and antioxidant capacity of thirteen faba bean (Vicia faba L.) genotypes cultivated in Tunisia. Food Res. Int.2011;44:970–doi:10.1016/j.foodres.2011.02.026
13. Kan L., Nie S., Hu J., Wang S., Cui S.W., Li Y., Xu S., Wu Y., Wang J., Bai Z., et al. Nutrients, phytochemicals and antioxidant activities of 26 kidney bean cultivars. Food Chem. Toxicol. 2017; 108: 467–477. doi: 10.1016/j.fct.2016.09.007.
14. Paredes, M., Becerra, V., & Tay, J. (2009). Inorganic nutritional composition of common bean (Phaseolus vulgaris L.) genotypes race Chile. Chilean Journal of AgriculturalResearch,69,486–495.:10.4067/S0718-58392009000400002
15. Baldi, G & Salamini, F. Variability of essential amino acid content in seeds of 22 Phaseolus species. Theoretical and Applied Genetics. 1973; 43, 75–78. doi:10.1007/BF00274960
16. Bressani, R, Elias, L G, & Navarrete, D A. Nutritive value of central American beans. IV. The essential amino acid content of samples of black beans, red beans, rice beans, and cowpeas of Guatemala. Journal of Food Science, 1961;26, 525–528. doi:10.1111/ jfds.1961.26.issue-5
17. World Health Organization. (2013). Health issues: Chronic diseases. Retrieved fromhttp://www.who.int/topics/chronic_diseases/e/
18. Reynoso-Camacho, R., Ríos-Ugalde, M. C., Torres-Pacheco, I., AcostaGallegos, J. A., Palomino-Salinas, A. C., Ramos-Gómez, M. . . . Guzmán-Maldonado, S. H. (2007). Common bean (Phaseolus vulgaris L.) consumptions and its effects on colon cancer in spraguedawley rats. Agricultura Técnica en México, 33(1), 43–52
19. Paredes, M, Becerra, V, & Tay J. Inorganic nutritional composition of common bean (Phaseolus vulgaris L.) genotypes race Chile. Chilean Journal of Agricultural Research. 2009; 69, 486–495. doi:10.4067/S0718-58392009000400002
20. Jenkins DJ, Wolever TM, Taylor RH, Barker HM, Fielden H. Exceptionally low blood glucose response to dried beans: comparison with other carbohydrate foods. Br Med J. 1980; 30;281(6240):578-80.
21. Jenkins DJ, Kendall CW, Augustin LS, Mitchell S, Sahye-Pudaruth S, Mejia SB, Chiavaroli L, Mirrahimi A, Ireland C, Bashyam B, Vidgen E. Effect of legumes as part of a low glycemic index diet on glycemic control and cardiovascular risk factors in type 2 diabetes mellitus: a randomized controlled trial. Archives of internal medicine. 2012 26;172(21):1653-60.
22. Syed IA, Khan WA. Glycated haemoglobin--a marker and predictor of cardiovascular disease. JPMA. The Journal of the Pakistan Medical Association. 2011; 61(7):690-5.
23. Bouchenak M, Lamri-Senhadji M. Nutritional quality of legumes, and their role in cardiometabolic risk prevention: a review. Journal of Medicinal Food. 2013; 1;16(3):185-98.
24. Singh B., Singh J.P., Shevkani K., Singh N., Kaur A. Bioactive constituents in pulses and their health benefits. J. Food Sci. Technol. 2017; 54:858 870. doi: 10.1007/s13197-016-2391-9.
25. Campos-Vega R, Loarca-Piña G, Oomah BD. Minor components of pulses and their potential impact on human health. Food Research International. 2010 1;43(2):461-82.
26. Lajolo FM, Genovese MI. Nutritional significance of lectins and enzyme inhibitors from legumes. Journal of agricultural and food chemistry. 2023; 50(22):6592-8.
27. Campos-Vega R, Loarca-Piña G, Oomah BD. Minor components of pulses and their potential impact on human health. Food Research International. 2010; 1;43(2):461-82.
28. Oberleas D, Harland BF. Phytate content of foods: effect on dietary zinc bioavailability. Journal of the American Dietetic Association. 1981 ;79(4):433-6.
29. Gibson RS, Yeudall F, Drost N, Mtitimuni B, Cullinan T. Dietary interventions to prevent zinc deficiency. The American journal of clinical nutrition. 1998 Aug 1;68(2):484S-7S.

30. Hoppler M, Zeder C, Walczyk T. Quantification of ferritin-bound iron in plant samples by isotope tagging and species-specific isotope dilution mass spectrometry. Analytical chemistry. 2009; 1;81(17):7368-72.
31. Murray-Kolb LE, Welch R, Theil EC, Beard JL. Women with low iron stores absorb iron from soybeans. The American journal of clinical nutrition. 2003; 1;77(1):180-4.
32. Hoppler M, Schönbächler A, Meile L, Hurrell RF, Walczyk T. Ferritin-Iron Is Released during Boiling and In Vitro Gastric Digestion, 3. The Journal of nutrition. 2008; 1;138(5):878-84.
33. Graf E, Eaton JW. Antioxidant functions of phytic acid. Free Radical Biology and Medicine. 1990; 1;8(1):61-9.
34. Fox CH, Eberl M. Phytic acid (IP6), novel broad spectrum anti-neoplastic agent: a systematic review. Complementary therapies in medicine. 2002; 1;10(4):229-34.
35. Grases F, Isern B, Sanchis P, Perello J, Torres JJ, Costa-Bauza A. Phytate acts as an inhibitor in formation of renal calculi. Front Biosci. 2007; 1;12(1):2580.
36. Habtamu Fekadu G. . Potential health benefits and adverse effects associated with phytate in foods: A review. Glob. J. Med. Res. 2014; 14, 23–31.
37. Pujol A., Sanchis P., Grases F., Masmiquel L Phytate intake, health and disease: “Let thy food Be thy medicine and medicine Be thy Food & rdquo. Antioxidants.2023;12,146.10.3390/antiox12010146
38. Raboy V. Myo-Inositol-1,2,3,4,5,6-hexakisphosphate. Phytochemistry. 2003; 64, 1033–1043. 10.1016/s0031-9422(03)00446-1
39. Haug W, Lantzsch H J. Sensitive method for the rapid determination of phytic acid in cereals and cereals products. J Sci and Food Agric. 1983; 34:1423 1426
40. Association of Official Analytical Chemists. Official Methods of Analysis, 2001. Phosphorus in Plants Micro Method
41. AACC Approved Methods of Analysis, 11th Ed. 40-40.01 Iron—Qualitative Method Cereals & Grains Association, St. Paul, MN, U.S.A.
42. Helbig E, de Oliveira AC, Queiroz Kda S, Reis SM. Effect of soaking prior to cooking on the levels of phytate and tannin of the common bean (Phaseolus vulgaris, L.) and the protein value. J Nutr Sci Vitaminol (Tokyo). 2003;49(2):81-6. doi: 10.3177/jnsv.49.81
43. Queiroz Kda S, de Oliveira AC, Helbig E, Reis SM, Carraro F. Soaking the common bean in a domestic preparation reduced the contents of raffinose-type oligosaccharides but did not interfere with nutritive value. J Nutr Sci Vitaminol (Tokyo). 2002 Aug;48(4):283-9. doi: 10.3177/jnsv.48.283.
44. Qureshi, S., & Hamid, A. Effect of overnight soaking and boiling on phytic acid, tannins, saponins and proximate composition in legumes. Journal of Pure and Applied Agriculture. 2020; 5(3), 17-25.
45. Wang N, Hatcher D W, Tyler R T, Toews R, Gawalko E. Effect of cooking on the composition of beans (Phaseolus vulgaris L.) and chickpeas (Cicer arietinum L.), Food Research International. 2010; 43(2),2010,589-594, https://doi.org/10.1016/j.foodres.2009.07.012
46. Ramírez-Ojeda A M, Moreno-Rojas R, Cámara-Martos F. Mineral and trace element content in legumes (lentils, chickpeas and beans): Bioaccesibility and probabilistic assessment of the dietary intake. Journal of Food Composition and Analysis, 2018; 73 (18): 17-28. https://doi.org/10.1016/j.jfca.2018.07.007.
47. Fernandes A. C., Nishida W., and da Costa Proença R. P., Influence of soaking on the nutritional quality of common beans (Phaseolus vulgaris L.) cooked with or without the soaking water: a review, International Journal of Food Science & Technology. 2010 45, no. 11, 2209–2218, 2-s2.0-78349288514, https://doi.org/10.1111/j.1365-2621.2010.02395.x.
48. Wang N., Hatcher D. W., Tyler R. T., Toews R., and Gawalko E. J., Effect of cooking on the composition of beans (Phaseolus vulgaris L.) and chickpeas (Cicer arietinum L.), Food Research International. 2010; 43, 2, 589–594, 2-s2.0-75149183539, https://doi.org/10.1016/j.foodres.2009.07.012
49. Brouns, F. Phytic acid and whole grains for health controversy. 2022; Nutrients; 14: 25