International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Impact Factor (2012): 3.358

Effect of Soaking on Functional Properties of Rice Bean-A Review

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Abstract: ***Vigna umbellata (Thunb.)Ohwi and Ohashi, previously Phaseolus calcaratus, is a warm-season legume, commonly called as rice bean and it is a mixed crop with maize, sorghum and cowpea. In this paper proximate composition of rice bean flour and its functional properties and effect of soaking on proximate composition, anti-nutritional factors, functional properties, cooking quality and PCMP number (protein phytate, calcium, magnesium and pectin content of the pulses) are reviewed.***

Keywords: Rice bean, soaking, phytic acids, polyphenols, legume flours

1. Introduction

Vigna umbellata (*Thunb.) Ohwi and Ohashi*, previously *Phaseolus calcaratus*, is a warm-season legume with yellow and small edible. It is commonly called rice bean or ricebean. It is regarded as a minor and fodder crop in agriculture and is often grown as intercrop or mixed crop with maize (*Zea mays*), sorghum (*Sorghum bicolor*) or cowpea (*V. unguiculata*), as well as a sole crop in the uplands, on a very limited area. Like the other Asiatic species, rice bean is a fairly short-lived warm-season annual. Rice bean grows well on a range of soils. It establishes rapidly and has the potential to produce high quality grain and large amounts of nutritious animal fodder.

The cultivated Asiatic *Vigna* species belong to the sub-genus *Ceratotropis*, a fairly distinct and homogeneous group, largely restricted to Asia, which has a chromosome number of 2n = 22 (except *V. glabrescens*, 2n = 44). There are seven cultivated species within the sub-genus. Rice bean's distribution pattern indicates great adaptive polymorphism for diverse environments, with its distribution ranging from humid tropical to sub-tropical, to sub-temperate climate. The presumed centre of domestication is Indo-China. It is thought to be derived from the wild form *V. umbellata* var *gracilis*, with which it is cross-fertile, and which is distributed from Southern China through the north of Vietnam, Laos and Thailand into Myanmar and India (Tomooka *et al.* 1991). Rice bean plays an important role in human, animal and soil health improvement. All varieties seem to be good sources of essential amino acids and minerals (Mohan and Janardhan, 1994), and the dried seeds make an excellent addition to a cereal based diet. Rice bean is most often served as a dhal either soaked overnight and boiled with a few spices or cooked in a pressure cooker. Apart from various recipes for dhal soup and sauces, pulses are also used in a number of other ways either in form of whole, cooked or roasted, as flour, or ground to make various deep fried dishes or snacks. Some recipes are specific to particular pulses, but many are open to substitution. The consumption of green pods as a vegetable has been recorded but is not widespread, although the indeterminate growth habit of many varieties is beneficial in providing a steady supply of green pods over long periods of the year. The raw protein content of rice bean is lower than that of most pulses. Gopinathan *et al.* (1987) noted that the protein content of related wild species (e.g. *Vigna minima*) tends to be higher than of cultivated lines, so there may be potential to breed for improved protein content. However, the amino acid with the general formula composition is reported by several authors to be well balanced for human consumption (Chandel *et al.* 1978; Mohan and Janardhan 1994; de Carvalho and Vieira 1996). As in other pulses, an important problem is that rice bean contains various anti-nutrients, notably phytic acid or phytate, polyphenols and fibers that reduce micronutrient uptake, in particular iron and zinc. While most legumes contain one or several enzyme inhibitors and similar anti-nutritive or toxic factors (Smil, 1997) the content of such substances appears to be low in rice bean. Phytate exists as Salts or esters of phytic acid containing inositol and phosphates as the base. They are abundant in the outer layer of cereals, in dried legumes and some nuts as both water-soluble salts (sodium and potassium) and insoluble salts of calcium and magnesium. In legumes a major portion of the total phosphorus is present in the form of phytic acid. Phytates may decrease absorption of calcium, zinc and iron from the intestine. Published reports indicate that phytic acid interacts with proteins to form complexes at acidic pH and low cation concentration by ionic interactions, while at alkaline pH; divalent cations mediate such formation of complexes between phytic acid and proteins (Deshphande and Cheryan, 1983). These protein phytate complexes are more resistant to proteolytic digestion as compared to protein alone at low pH of the stomach and are thought to be responsible for the reduced bioavailability of minerals (De Rhea and Jost, 1979 and Erdman, 1979).Tannins form complexes with proteins, carbohydrates and other polymers in food as well as with certain metal ions such as iron under suitable conditions and appropriate pH. The greater tendency of tannins to form complexes with proteins than with carbohydrates and other food polymers may explain the low digestibility of legume protein. The rice bean varieties having a dark color seed coat had a higher concentration of polyphenols than those having a light color. Soaking usually forms an integral part of bean processing methods such as cooking, germination, fermentation and roasting. Soaking of beans facilitates quicker cooking. This is a particularly true when dry beans are used for canning in commercial production (Nordstrom and Sistrunk, 1977). Soaking media include water, salt (or a combination of salts), and alkali and the soak water may or may not be discarded prior to cooking depending on regional preferences. Such practices may influence the nutritional quality of beans. Soaking and cooking of legumes result in significant reduction in phytic acid and tannin contents. Maximum reduction of phytic acid (78. 05%) and tannin (65.81 %) was found for sodium bicarbonate soaking followed by cooking. These treatments also result in a slight reduction in nutrients such as protein, minerals and total sugars. It has been known since the third century BC that certain changes occur in legume seeds during extended storage, especially at high temperatures and humidity, making them difficult to cook. This hard to cook phenomenon is a result of several hypothesized changes at the molecular level. The pectin-cation-phytate theory suggests that during storage an intracellular enzyme, phytase, hydrolyzes phytin, resulting in the release of divalent cations. Once cooking begins, monovalent cations from the pectin located in the cell wall exchange with those divalent cations to form insoluble pectin, become extremely strong and make long stored legumes difficult to cook. This phenomenon is expressed through a term called "PC MP number" which determines the hardness of the bean. Certain water soluble, nutritionally important minerals and vitamins may also be lost to soak water, if discarded, along with undesirable components such as flatulence causing oligosaccharides, phytates and polyphenols. Kadam *et al.* (1981) reported that soaking of horse gram in a salt solution of 1.5% $NaHCO_3$, 0.5% Na_2SO_3 and 0.75% citric acid for 12hr caused reduction in cooking time from 145 min to 27 min. They also observed 69 to 73% improvement in protein digestibility and 35 % less polyphenols in cooked horse gram. The effects of pre soaking of pulses in the salt solution of several chemicals in reducing the cooking time of pigeon pea splits (Narsimha and Desikachar, 1978), peas (Bongirwar and Sreenivasan, 1977), beans (Rockland and Mertzler, 1967 and Iyer *et al.* 1980), winged bean (Naryana, 1981) and pigeon pea, chickpea, black bean, mung bean and lentil dhals (Chavan *et al.* 1983) have been reported.

2. Proximate Composition of Rice Bean Flour

The raw protein content of rice bean cultivars appears to be lower than of most other pulses, although there is considerable variation in the figures presented in the literature.

Author Percentage	
Malhotra *et al.* (1988)	17.5 - 23.1
Mohan and Janardhan (1994)	21.9 - 26.1
Saikia *et al.* (1999)	16.9 - 18.0
Rodriguez and Mendoza (1991)	17.3 - 21.4
Saharan *et al.* (2002)	18.2 ± 0.2
Duke (1981)	20.9
FAO (1982)	18.5
Chandel *et al.* (1978) 14.0-24.0	
Kaur and Kapoor (1992)	17.2 – 18.5
Overall range	**14.0-26.**

Duke (1981) gave the following figures for mineral content per 100 g of rice bean: 200 mg Ca, 390 mg P, and 10.9 mg Fe. Analyses of the rice bean revealed an ash content of 4.03%. Malhorta *et al.* (1988) reported that carbohydrate content of the bean ranges from 58. 15-71.99%. Kaur and Kapoor (1992) reported that total soluble sugars, non-reducing sugars, starch and total available carbohydrates of five high yielding rice bean varieties varied from 5.0g to 5.6g, 4.4g to 8.3g, 52.4g to 60.1g/100g, respectively. In the case of starch and total available carbohydrates there were no significant varietal differences; whereas some significant varietal variations were observed in respect to total soluble sugars, reducing sugars and non-reducing sugars. The mineral content of 5 different varieties of rice bean and the concentrations of calcium, phosphorus and iron of rice bean varieties varied from 287mg to 327mg, 234mg to 249mg and 6.3mg to 7.7mg per 100gm respectively. In rice bean the extractability of calcium was the highest (about 88%) and phosphorus was the lowest (33%). The concentrations of the other minerals were comparable in all the legumes studied. They also reported that fat content of the bean ranged between 0. 44g and 0. 56g per 100 g in five different varieties. Mohan and Janardhanan (1994) reported that Ca and Mg content of the bean as 264 mg and 73 mg respectively per 100g of rice bean. Saikia *et al.* (1999) found 0.46-0.52% crude fats (fatty acids and fat soluble constituents) in uncooked rice bean.

3. Effect of soaking on proximate composition of legume flours

Egbe and Akinyele (1990) reported that decrease in crude protein content of lima bean during soaking was due to leaching of water soluble nutrients into the soaking water. Rehman *et al.* (2 001) reported that soaking significantly reduced the total sugars and starch content of kidney beans. Mubarak (2005) reported decrease in fat and ash during soak treatment of mung bean might be attributed due to leaching or their diffusion into the soaking water. Magadi (2007) reported a significant increase in moisture content during soaking with a relative decrease in protein and ash content during Soaking and cooking which might be attributed due to the leaching of soluble proteins and minerals.

3.1 Antinutritional factors

a) Phytic acid

Kaur and Kapoor (1992) found between 1875 and 2270 mg phytic acid in their analysis on five high yielding rice bean varieties. Phytic acid has been known to be the major storage form of phosphorus, and in dry legumes it has been reported to vary from 0.44 to 1.46%. It is known to be involved in undesirable processes including those leading to hard cook phenomenon. This adverse attribute increases cooking time and is important to people in developing countries where energy sources including fuel wood are becoming increasingly scarce and expensive. Saikia *et al.* (1999) found from 1998 to 2170 mg phytic acid / 100 g uncooked rice bean, but substantial reduction after pressure cooking or boiling. Saharan *et al.* (2002) measured 2018 ± 5. 9 mg / 100 g. Rice bean has a fairly high content of phytic acid and its content among cultivars varied significantly. He further reported that the high content of phytate is of nutritional significance as not only is the phytate phosphorus unavailable to the human, but it also lowers the availability of many other essential minerals.

b) **Polyphenols**

Mosely and Griths (1979) reported that tannins are responsible for affecting the digestibility of dietary protein and, to a lesser extent, that of available carbohydrate and lipid. He further revealed that tannins form complexes with proteins, carbohydrates and other polymers in food as well as with certain metal ions such as iron under suitable conditions and appropriate pH. Desphande and Cheryan (1983) observed that rice bean varieties having a dark color seed coat had a higher concentration of polyphenols than those having a light color. The concentration of tannins in the seed of the legumes thus seems to be a function of the color of the seed coat Salunkhe *et al.* (1982) reported that polyphenols in legumes and cereals are regarded as antinutritional factors, due mainly to the effects of tannins, which reduce protein digestibility and the inhibitory effect of these compounds on the activites of digestive enzymes like trypsin, lipase and amylase reduce the digestibility of the protein and carbohydrates and the availability of vitamins and minerals. Malhotra *et al.* (1988) reported polyphenols to be 900 mg/100g in rice bean lower than that in other 'standard crops cowpea, moong, mash'. Kaur and Kapoor (1992) found between 1279 and 1587 mg polyphenols per 100 g in five varieties. Anton *et al.* (2008) reported that total phenolic content was substantially higher in the isolated seed coats of navy and pinto beans than in the whole bean. The high concentration of phenolic components in the bean hull was likely responsible for the increased antioxidant activity of the hull fraction.

3.2 Effect of Soaking on Phytic Acid and Polyphenolic Content of Legume Flours

Sathe and Salunkhe (1981) and observed a marked decrease in tannin equivalent of winged bean during soaking. A successive and significant reduction in polyphenols content was found in all the pulses with progressive increase in soaking period. Since polyphenolic compounds are present on the periphery of the grain, their passing out in to the soaking medium through the seed coat is possible. This may explain the loss of polyphenols during soaking.Deshpande *et al.* (1983) reported that tannin content was reduced by 68.0 to 94.6% using a dehulling process. Data suggests that much of the phenolics in beans are in the hull. Treatments that involve removal of the hull (i.e. dehulling) or manipulation of the hull such as soaking will affect phenolic content. Processes involving heat may also reduce phenolic compounds. Reddy *et al.* (1982) observed that the phytate could be substantially eliminated by Soaking and cooking. The present decrease in phytic acid content in soaked rice bean was comparable to the report of Kataria *et al.* (1989).Kaur and Kapoor (1992) observed that ordinary cooking of unsoaked and soaked seeds decreased the phytic acid content in all the pulses which varied significantly among the rice bean varieties. They also reported cooking of soaked seeds caused a greater reduction in the phytic acid than cooking of unsoaked seeds. El hady and Habiba (2003) observed a 36% reduction in phytic acid and 17% reduction in phenolics and tannin contents in kidney beans after an overnight soaking in water at room temperature. Luthria and Pastor corrales (2005) reported that only 1 and 2% of the phenolic acids were found in the water used for soaking great Northern and black beans, respectively. In their particular experiment, specific phenolic acids were measured. Thus, phenolic compounds other than phenolic acid may account the high losses observed by some researchers during bean soaking. In contrast, research shows that a significant reduction in total phenolic content occurs during a process that combines Soaking and cooking. Nergiz and Gokgoz (2007) reported 57-58% reduction in phytic acid after cooking beans that had been soaked 12hr prior to cooking. Boateng *et al.* (2008) also observed as slight decrease in total phenolic content and tannin levels in soaked kidney and pinto beans. However, higher flavonoids levels were observed in the soaked pinto beans. Nuzhat huma *et al.* (2008) revealed that dark colour legume (red kidney beans) has a high level of phytic acid and tannin compared with light colour (white kidney beans and white grams). He further revealed that soaking and cooking of legumes resulted in significant reduction in phytic acid and tannin contents. Maximum reduction of phytic acid (78.05%) and tannin (65.81 %) was found for sodium bicarbonate soaking followed by cooking. These treatments also result in a slight reduction in nutrients such as protein, minerals and total sugars.

3.3 Effect of Soaking on Functional Properties of Legume Flours

Hsu *et al.* (1982) found that the lowest solubility of the protein of yellow pea, lentils and faba bean were at pH 4.5-5.0. On either side of pH 5 the protein solubility started to increase and reached its maximum value at pH 12 (88%). Bencini and Carcea (1986) studied the functional properties of drum dried chick pea which is soaked in $NaHCO_3$ medium milled and passed through 60 mesh sieve reported a bulk density of 0.61g/ml, oil absorption capacity of 1.21g, foaming capacity of <8% and foam stability less than 11ml after 120 min. The least gelation concentration of 14% showed that there is no remarkable effect of soaking in $NaHCO_3$ medium. Pawar and Ingle (1988) studied the functional properties of beans which were soaked in salt solution for 3, 6, 9 and 12hr and observed that water and oil absorption capacity of flour and protein were increased significantly whereas nitrogen solubility, foaming and emulsion properties were decreased significantly. However, gelation remained more or less constant. The nitrogen solubility was. The nitrogen solubility profile of soaked moth bean flours was decreased at all pH and minimum at pH 4.5. The decrease was more conspicuous at pH 2.0, 3.0, 8.0, 9.0, 10.0, 11.0 and 12.0. Giami (1993) studied the effect of soaking on functional properties and found that cowpea when dehulled, blanched and given a soak treatment at 35°C for 10 hr reported an oil absorption capacity of 1.30 g and water absorption capacity of 5.05g. They also observed cow pea when defatted and milled had shown a decrease in 29% of foam volume over 120 min. - Kaur and Singh (2005) found an emulsification activity and emulsification stability of 82.1% in defatted kabuli chickpea which is milled and passed through 72 mesh sieve. Sanjeewa *et al.* (2009) measured the water absorption capacity of chickpea which is soaked in water at room temperature for 40 min and dried to 10-11% moisture content in hot air drier at 50 -60°C and milled absorbed 1.20 g per a gram of sample which is low compared to flour of untreated chickpea. Siddiq *et al.* (2009)

reported that red kidney bean when soaked dried and passed through Hammer mill posses' water absorption capacity of 2.25 g per gram of sample.

3.4 Effect of soaking on cooking quality and PCMP number of legume flours:

Rockland and Metzler (1967) soaked Lima and other beans in mixed salt solution of 1.5% $NaHCO_3$, 0.5% Na_2CO_3, 2.5% NaCl and 1% sodium polyphosphate and observed significant effect of this soak solution in reducing the cooking time. The effect of presoaking of legume seeds in the soak solution of chemicals in reducing the cooking time of peas has been reported. Muller (1967) found that the main factor affecting the cooking quality of seeds of several pea and bean varieties was found to be phytin, Ca, Mg and free pectin. Other factors probably involved were the thickness of the seed coat, palisade layer and the contents of lignin and alpha-cellulose in the seed coats. Cell contents had no detectable effect. Bongirwar and Sreenivasan (1977) developed a process for the production of quick cooking dehydrated peas from dry commercial peas. It involved hydrating the peas by soaking in 0.25% sodium bicarbonate solution for 5hr, pricking the soaked peas for 10 min followed by precooking for 4 min at 1.05 kg/sq gauge pressure and dehydrating the precooked peas in a standard tray drier at 55 to 60^{0}C for 2 to 2.5hr to reduce the moisture content to about 8%. Narsimha and Desikachar (1978) determined the cooking time, water uptake, dispersed solids into cooking water, contents of minerals, protein and PCMP (a) pectin (Ca + ½ Mg)/phytin or (b) pectin (Ca + 1/2Mg) – phytin numbers for ten varieties of pure bred pearled *tur* (*Cajanus cajan*). The hydration of the dispersed solids during progressive cooking (0-80 min) of 4 varieties of polished (15%) and unpolished tur were also determined. They used chemicals for reducing the cooking time of split red gram (*Cajanus cajan*). Sodium carbonate, sodium bicarbonate, trisodium phosphate and ammonium carbonate either alone or in combination were either (a).added to cooking water (0.5-1%) or (b) coated on to dhal and dried or (c) the dhal was soaked in chemical solutions (0.75-1.5g/100g dhal) for 2hr, drained and washed off the soaked dhal prior to cooking. Combination of trisodium phosphate and ammonium carbonate or sodium carbonate and sodium bicarbonate reduced cooking time by 50%. Treatment (b) was more effective than (a), trisodium phosphate was not preferred as it left a bad taste. Rizley and Sistrunk (1979) observed that peas when soaked in pyrophosphate solution gave a lighter colour, whereas soaking in bicarbonate solution gave a less desirable colour but a softer texture and better flavor. They further observed that longer soaking time results in greater discoloration. Shinde and Shiralkar (1980) used ammonium chloride, sodium acetate, ammonium phosphate, sodium dihydrogen phosphate, EDTA, sodium bicarbonate, sodium chloride, EDTA + sodium bicarbonate at 0.5% w/v to reduce the cooking time of dry beans of rajmah (*Phaseolus vulgaris*). Of these chemicals only sodium bicarbonate and EDTA alone or in combination reduced the cooking time from 10 to 3 min. Kadam *et al.* (1981) reported that soaking of horse gram in a solution of 1.5% $NaHCO_3$, 0.5% Na_2CO_3 and 0.75% citric acid for 12hr was found to be effective in reducing cooking time from 147 to 27 min. They also observed 67% reduction in cooking time of moth bean on soaking in salt solution for 12hr. Silva *et al.* (1981) found that a salt combination of soaking solution was most effective in promoting bean softening during cooking compared to no soaking or a distilled water soak to black beans (*Phaseolus vulgaris).* Narayana (1981) determined cooking characteristics such as hydration, dispersion of solids and cooking time of winged bean dhal. He observed that salts such as ammonium carbonate (0.5%) with either sodium carbonate or bicarbonate (0.5%) reduced the cooking time nearly 50% and direct addition of these chemicals to the cooking water imparted an alkaline taste and undesirable color. However, coating of the dhal with the chemicals or presoaking in solution of these salts eliminated these disadvantages. Pawar (1986) observed that water uptake and leaching losses of solids were increased after soaking of blanched moth beans in either distilled water for 12hr or in salt solution containing $NaHCO_3$, Na_2CO_3 and citric acid pH 7.0± 0.05 for 3, 6, 9 and 12hr and cooked traditionally. The cooking time and polyphenols content were found drastically decreased, on soaking in salt solution, from 22 to 5 min (77.27% and 1.32 to 0.8% respectively). Vimala and Pushpamma (1987) reported the water absorption (102±125%) and solid dispersion (10±12%) of rice bean were comparable, more or less, to the reported value of black gram . In their study they found that water absorption and per cent solid dispersion were key aspects of cooking quality because the higher the values for these parameters the better is the liking for the cooked pulse. Paredes lopez *et al.* (1989) Cooking time and seed hardness were increased by growing beans in a location with soils rich in Ca and Mg and higher average annual temperature (15–24°C), compared to a location with lower temperature (11–18°C) and soils poor in Mg and P. Kilmer *et al.* (1994) observed insolubilisation of the pectic substance due to the activation of phytases, phytate degradation during storage, release of cations and eventual cross linking of pectins by formation of Ca and Mg pectinates, render the cells resistant to water penetration and swelling and to the subsequent failure of adjacent cells to separate upon cooking. Ockenden *et al.* (1997) reported loss of phytate in beans is faster at high temperature and relative humidity during storage, conditions that enhance the hard-to-cook defect. The water uptake was monitored by soaking 16 g of beans in 100 ml of distilled water at 25°C until a complete soaking was achieved. Neelam khetarpaul *et al.* (2005) found that the cooking time of untreated soy dhal was 162 min; it reduced significantly by 58-98 per cent when soaked in 0.5, 0.75 and 1 per cent solutions of sodium carbonate and sodium bicarbonate for 3, 6 and 9hr. The percentage reduction in cooking time was found to be greater when soy dhal was soaked in sodium carbonate solution; however, this adversely affected the colour and flavour. In contrast, soy dhal soaked in sodium bicarbonate was found to be acceptable to the human palate. Zhao and Chang (2008) studied the effect of soaking on cooking quality in peas, lentils and chickpeas which were blanched and soaked in water, then cooked with four different cooking methods and dehydrated in a convection tray dehydrator. Dehydrated yellow and green peas produced by Soaking at 22^{0}C for 9 h and 82^{0}C for 4 h in 0.07% $NaHCO_3$ solution, and followed by precooking at 110^{0}C for 10 min had the best quality with respect to firmness, splitting and butterflying rate. Dehydrated chickpeas produced by Soaking at 22^{0}C for 9 h and 82^{0}C for 3 h in 0.07% $NaHCO_3$ solution, and followed by precooking at 110 C for 10 min had the best quality. Dehydrated lentils produced by Soaking at 22^{0}C for 2 h and 82^{0}C for 20 min in 0.07% $NaHCO_3$ solution, and followed by precooking at 106 ^{0}C for 10 min had the best quality. Golam and Tzen (2010) reported the cooking time of untreated Kalimatar seed was 187 ± 3.15 min; soaking the seeds in different media for 12hr reduced the cooking time considerably. Sodium carbonate solution (2%) was found as the most suitable soaking medium, particularly followed by roasting the seeds. Soaking and/or roasting did not cause pronounced reduction in nutrient content of the sample. Sasikala and Narasimha (2010) reported the hardness values of green gram and horse gram and their effect on soaking. The soaking effects on the texture of whole as well as dehulled split green gram and horse gram were studied using universal texture machine and scanning electron microscopy. The hardness values of raw whole legumes of green gram (67.5–69.9 N) and horse gram (186.5–245 N) decreased to 45.3–57.4 N and 137.8–207.8 N, respectively, after 1hr soaking.

4. Conclusion

Application of blanching preceded by soaking of rice bean seeds, thus offers the dual advantage of saving valuable fuels by shortening cooking time, as well as rendering the seeds more acceptable to consumers. Soaking of legumes reduce their anti-nutrients; phytic acid and tannin significantly. These treatments may be used domestically as well as commercially to increase the nutrients' availability from legumes to meet the problem of protein and minerals deficiencies. In addition, soaking blanched seeds prior to cooking is more appropriate than cooking for more time from the point of view of fuel consumption and texture. The rice bean treatments examined in this study can thus be used for food preparation. However, these results are obtained on laboratory scale. Further studies on soaking of rice bean using other types of salt solutions on pilot scale are needed to undertake for better utilization of underutilized crops such as rice bean and development of pulse based products with high protein content.

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