ASEAN
Journal of Scientific and Technological Reports
Online ISSN:2773-8752

Research article

Germination-Mediated Alterations in Physicochemical, Functional and Cooking Properties of Vigna aconitifolia Flour

Venipriyadharshini Loganathan[1*], and Kavitha Kandhasamy[2]

[1] Department of Nutrition and Dietetics, Periyar University, Salem, India; 636 011
[2] Department of Foods and Nutrition, Vellalar College for Women, Erode, India, 638 012
* Correspondence: venicnd@gmail.com

Citation:
Longanathan, V.; Kandhasamy, K. Germination-Mediated alterations in physicochemical, functional, and cooking properties of vigna conitifolia flour. *ASEAN J. Sci. Tech. Report.* **2025**, *28*(4), e258185. https://doi.org/10.55164/ajstr.v28i4.256897.

Article history:
Received: November 20, 2024
Revised: May 26, 2025
Accepted: June 11, 2025
Available online: July 25, 2025

Publisher's Note:
This article has been published and distributed under the terms of Thaksin University.

Abstract: A *Vigna aconitifolia (V.aconitifolia),* also known as moth bean, is a nutrient-rich legume that is commonly consumed in many parts of the world. Germination is a process that can enhance the nutritional and functional properties of legumes. However, there is limited information on the effects of germination on the physicochemical, functional, and cooking attributes of *V. aconitifolia.* The objectives of this study were to evaluate the effects of germination on the physicochemical, functional, and cooking attributes of *V. aconitifolia* and to compare the properties of germinated and ungerminated *V. aconitifolia* seeds. Seeds were germinated for 24 hours and then dried and milled into flour. The physico-chemical properties of the flour, including moisture content, ash content, and pH, were evaluated. The functional properties, including water absorption, oil absorption, and emulsification capacities, were also evaluated. The cooking characteristics, including cooking time, water uptake ratio, and swelling power, were evaluated using standard methods. The results showed that germination significantly improved the physicochemical properties of *V.aconitifolia*, including moisture content, ash content, and pH. The functional properties, including water absorption, oil absorption, and emulsification capacities, were also significantly improved. The cooking characteristics, including cooking time, water uptake ratio and swelling power, were significantly reduced. The results suggest that germination can enhance the nutritional and functional properties of *V.aconitifolia*, but may also affect its cooking characteristics. The findings of this study have significant implications for the food industry, as they suggest that germination can be a simple and effective method to enhance the quality and functionality of legume flours.

Keywords: *V.aconitifolia*; germination; physico-chemical & functional properties; cooking characteristics; nutritional quality

1. Introduction

Vigna aconitifolia (V.aconitifolia), a nutrient-rich legume native to western and northern India, has been an underutilized crop in regular diets, despite its potential as a valuable source of protein, fiber, and antioxidants [1]. This legume plays a vital economic role, particularly in rural India, where it serves as a cash crop, providing income for farmers. Moreover, *V.aconitifolia* 's nutritional profile makes it an attractive alternative to cereals, which dominate Indian diets but often lack protein digestibility [2].However, *V.aconitifolia's utilization is hindered by limitations such as low protein digestibility,* *high phytic acid content, and a* coarse texture. Germination, a cost-effective and straightforward processing technique, has been shown to enhance the nutritional and functional properties of legumes[3]. This process involves soaking, sprouting, and drying the seeds, which activates enzymes that break down phytic acid and other anti-nutrients. Germination has been demonstrated to improve protein digestibility, mineral bioavailability, and antioxidant activity in *V.aconitifolia* [4].The findings of this study have significant implications for the food industry, particularly in the development of novel, nutrient-dense food products. By enhancing the nutritional and functional properties of *V.aconitifolia*, germination can unlock new opportunities for food manufacturers, processors, and marketers. Moreover, the increased availability of nutrient-rich, germinated *V.aconitifolia* can contribute to addressing malnutrition, promoting sustainable agriculture, and supporting the growth of the food industry in India and beyond.

2. Methodology

2.1 Selection and Processing of *V.aconitifolia*

V.aconitifolia (moth bean) is a nutrient-rich legume that is widely cultivated in Tamil Nadu, India. Two genotypes of *V.aconitifolia*, TN 12 (wild type) and TN 27 (cultivation), were identified by Tomooka et al. [5] and Tomooka et al. [6]. Based on cultivation and availability throughout the year, TN 27 was selected for this study. The selected variety was procured from farmers in the Namakkal district of Tamil Nadu. The legume was manually winnowed to remove dust and other unwanted solid matter. The selected legume was authenticated by the Botanical Survey of India, Southern Regional Center, Coimbatore, Tamil Nadu. The *V.aconitifolia* seeds were cleaned, washed, and sun-dried at 38°C for 24 hours. The seeds were then roasted in an iron tawa and finely powdered using a high-speed food processor equipped with a stainless steel blade. The powder was processed to achieve a uniform particle size, passing through a 60-mesh sieve (particle size ≤ 250 μm). The powder was stored in an airtight container for later use.

2.2 Germination

The germination process of *V.aconitifolia* was initiated by selecting healthy, mature seeds. To prevent fungal growth, the seeds were washed with distilled water to remove any residual mercuric chloride, and then soaked in distilled water for 8 hours to facilitate germination. The soaked seeds were transferred to a germination tray lined with moist paper towels, covered with a thin layer of moist paper towels, and maintained at a temperature of 25°C and relative humidity of 80%. The seeds were allowed to germinate for different periods, namely 12, 24, 36, and 48 hours, and monitored for changes in color intensity, which was evaluated using a subjective scale (High, Medium, Low). The color intensity was recorded at each time point to assess the progression of germination. The germination process was terminated by drying the germinated seeds in a hot air oven at 50°C for 2 hours [7].

2.3 Physicochemical characteristics of Ungerminated and Germinated *V.aconitifolia* Flour

The physical characterization of *V.aconitifolia* was determined, as its characterization indicates the adaptability of the legume. Analyzing the physical characteristics of the legume is most important, as it helps to anticipate the performance of the legume. The most common parameters used for assessment were shape, size, weight, volume, sphericity, and Density [8]. The understanding of the physical characterization of legumes, such as surface area, true density, sphericity, volume, bulk Density, projected area, and dimensions, is crucial to counter the difficulties and enhance the capacity of the legume during post-harvesting, processing, and storage. The procedure followed is explained under the following headings. Physico–chemical properties influence the processing, storage period, preparation process, and consumption, and hence, palatability increases when the quality of physico-chemical reactions is within a proper range [9]. The following physicochemical characteristics of *V.aconitifolia* flour (ungerminated and germinated) were studied using standard procedures (triplicate):

2.3.1 Thousand Legume Weight

The thousand legumes were randomly selected and weighed using an electronic weighing balance. The weight of *V. aconitifolia* was taken as the mean of triplicate measurements and noted in grams [10].

2.3.2 Thousand Legume Volumes

The thousand selected legumes were taken in a measuring cylinder. A measured quantity of distilled water (250 ml) was added, and the difference obtained was recorded in milliliters [10].

2.3.3 Length, Breadth, and Thickness of the Legume

The three dimensions were calculated by taking an average of 100 legumes using a vernier caliper (least count = 0.01 cm). If the arrangements of starch matrix in the granules are high, then the thickness of the legume or granule strip is also high [11-12].

2.3.4 Equivalent Diameter

The equivalent diameter or geometric mean of the *V.aconitifolia* was determined by using the given formula by Mohesenin [13]. The measurements were expressed in mm.

$$Dm = (LBT)^{1/3}$$ Where L= length, B= Breadth, T=Thickness

2.3.5 Sphericity

The sphericity of the ungerminated and germinated *V.aconitifolia was* determined as the proportion of the volume of the seed with the same surface area as a sphere. It is calculated by the given formula [14].

$$S\phi\ (\%) = (l \cdot b \cdot t)1/3 \div l$$

2.3.6 Density

The Density of *V. aconitifolia* was determined using the formula Mass/Volume, where V = ((l) × (b) × (h)), and it is expressed in mm. Less moisture and crystallinity result in less Density [11].

2.3.7 Standardization of Germination

The *V.aconitifolia* was soaked for 12 hours and allowed to germinate over four different periods, as follows, and the growth of the sprout was noted [15]. The temperature was under control at 300 °C (Table I). The International Seed Testing Association (ISTA) has standardized testing procedures for several medicinal plants and seeds. It also exposed the procedures [16]. The calculated parameters included shoot length, seed germination, and weight [17]. The properties of germinated legumes with different germination hours were calculated and discussed in the results.

2.3.8 Bulk density

Bulk Density of ungerminated and germinated *V.aconitifolia* flour was calculated by the measurement of proportion of mass of the legumes to its volume in total (Ungerminated & germinated) was determined (g/ml) by the formula and method used in the article Shreelalitha [14]. When the physicochemical factors of a legume are said to be beneficial, the impact of anti–nutritional factors in the legume will be lower [10].

2.3.9 True Density

True Density of *V.aconitifolia* flour (Ungerminated & germinated) was estimated by the method of sand displacement [18]. When the moisture content is high, the true density will decrease. True density was determined by the following equation quoted by Matouk et al. [19].

$$Pt = \frac{Ms}{V1}, kg/m3.$$

Where, Pt True Density of *V.aconitifolia*, kg/
$M^{3;}$ $M_{s;}$ Weight of the *V.aconitifolia*, kg;

$V_{i:}$ Displaced Volume of Toluene, M^3

2.3.10 Porosity

Porosity of *V.aconitifolia* flour (Germinated & ungerminated) was estimated by measuring the percentage of space of the inner volume of the legume into the volume of legume bulk [19].

Porosity = P1-P2/ P2
Where P= Porosity of *V.aconitifolia* flour (%);
P1 – Constant pressure inside the tank 1
P2 - Constant pressure inside the tanks 1 and 2

2.3.11 Scanning Electron Microscope (SEM)

SEM analysis was done in the laboratory of Periyar University a clear picture of starches present in ungerminated and germinated *V.aconitifolia* (The morphological study of starch)were recorded with the magnification of 300x, 1000x 2000x, 3000x and 5000x with the range of 100µm,20 µm, 10µm,10 µm and 5 µm(Make: Carl Zeiss Microscopy GmbH Germany). The SEM analysis helps in understanding the structure of films present in both ungerminated and germinated *V.aconitifolia* flour [11].

2.3.12 Fourier Transform Infrared (FT-IR) Spectra

V.aconitifolia germinated, and a PerkinElmer FT-IR spectrophotometer analyzed non-germinated flour to find the chemical composition of the flour qualitatively; a Vector 22 model made inGermany was used to record the FT–IR in solid state with the Frequency range – 4000 – 400 cm^{-1}[20].

2.4 Functional characteristics of Ungerminated and Germinated *V.aconitifolia* Flour

The good functional properties of legumes result in good output during processing, storage, development, and consumption of the food product. The functional characterization of *V.aconitifolia,* which includes Water absorption capacity, Oil absorption capacity, water solubility index, foaming capacity and index, emulsification, and antinutritional factors, was determined as it determines the quality of the legume. A functional characteristic purely depends on the activities of physicochemical properties, structure, and composition of the legume [14]. The functional properties of legumes depend on the structure and composition of proteins and amino acids, as well as the influence of other external components [21]. The procedure followed is explained under the following headings

2.4.1 Water Absorption Capacity

Water Absorption Capacity (WAC) is used to determine the legume's ability to absorb water. The assessment is more important because legumes that possess lower WAC have less water-holding capacity, resulting in a poor food product. Legumes that possess high WAC have a high water-holding capacity, which results in achieving brittle and dry conditions [9]. WAC was determined by adding 40 mL of water to the mixture of 2 g of *V. aconitifolia* flour and stirring well at a continuous speed for one hour using a Griffin flask shaker. The mixture was then centrifuged at 220 rpm for 10 minutes. The following formula was used for the calculation of the capacity of water absorption [22], and the results obtained were denoted in grams/grams

$$WAC = \frac{Final\ weight\ -\ initial\ weight}{initial\ weight}\ X\ 100$$

2.4.2 Oil Absorption Capacity

Oil Absorption Capacity (OAC) or Fat Absorption Capacity (FAC) was high when the legume contains a high amount of fibre, because of the fibre's capability of holding or trapping fat ata higher level [9]. OAC was determined by the reference of Shuang et al. [23]. 2.5 g of both the ungerminated and germinated *V.aconitifolia* flour in separate test tubes were mixed with peanut oil (30 mL). The mixture was stirred for one minute, left undisturbed for 30 minutes, and then centrifuged for 30 minutes at 3000 g. When the oil formed as a separate layer, it was filtered out using a pipette, and the remaining oil was removed by keeping the tube inverted for 30 minutes. The quantity of oil absorbed by the sample was measured and denoted in grams per gram.

2.4.3 Water Solubility Index

Water solubility index indicates the quantity of the polysaccharide present or released from the legume by adding excess water. The mixture was constantly stirred to control the higher speed during centrifugation and also to prevent the putrefaction of the starch granules. Both samples were heated in a controlled temperature environment at 85 °C for half an hour with continuous stirring. After heating, the samples were kept outside to cool down to room temperature. The samples were centrifuged at 560g for 15 minutes. The capacity of solubility was determined by evaporating the supernatant solution. The remaining residues were weighed. Using the formula provided below, the water solubility index was calculated [22].

$$\text{WSI (\%)} = \frac{\text{Weight of the dissolved solid in supernatant}}{\text{weight of the dry solids}} \text{X100}$$

2.4.4 Foaming Capacity and Stability

Foaming capacity was determined by the reference of Salma, H. A., Nahid et al. [24]. 2g of the sample was mixed with 10 ml of buffer solution at pH ranges in a blender (Moulinex) for 2 minutes at "HI" speed. The blended mixture was transferred to a measuring cylinder (250 ml) After 30 seconds, the volume of foam was measured and noted in %.

$$\text{FC (\%)} = \frac{\text{Volume of flour after whipping} - \text{Volume of flour before whipping}}{\text{Volume of flour before whipping}} \text{X 100}$$

Where FC = Foaming Capacity

Foaming stability was determined using the same procedure, but the volume of foam was measured after a 15-minute time interval. The formula used was taken from the reference of Nahid etal. [24], and it was given below

$$\text{FS (\%)} = \frac{\text{Foam volume of the flour after 15 minutes}}{\text{Initial foam volume of the flour}} \text{X100}$$

Where FS = Foaming Stability

2.4.5 Emulsification Capacity

The capacity used to determine the emulsifying property of the legume flour was determined by the method followed by Shuang et al. ([23] and Adeleke and Odedeji[25]. 3.5 g of ungerminated and germinated *V.aconitifolia* flour was mixed with distilled water in a separate test tube and homogenized at 10,000 rpm for 30 seconds using a High-Speed Homogenizer. Then another 25 ml of oil (peanut) was mixed with the same sample and homogenized for another 90 seconds. The formed emulsion was equally divided and transferred into centrifuge tubes, which were then centrifuged for 5 minutes at 1100 g. The capacity of emulsification was calculated by dividing the volume of foam produced after centrifugation by the volume before centrifugation.

2.5 Cooking Characteristics of Ungerminated and Germinated *V.aconitifolia* Flour

When compared to the utilization of pulses, the use of food in the form of legumes is less due to multiple factors. The hardness present in the legumes makes difficult to cook and decreases the palatability; inhibiting enzymes etc but good quality cooking can help in counteract those factors [26]. cooking characteristics of the legume can be assessed to precise the value of a legume to develop a good food product and also for the process of incorporation of a food product.

2.5.1 Optimum Cooking Time (min)

The cooking time of *V.aconitifolia* was determined by cooking 2g of *V.aconitifolia* grains in 20 ml of distilled water. The distilled water was kept in a 100 ml beaker and heated using a boiling water bath. The *V.aconitifolia grains were taken after 25 minutes of cooking and pressed between two plates;* the time taken for optimum cooking was recorded [14].

2.5.2 Water Uptake Ratio (%)

The water uptake ratio of *V.aconitifolia* grains was calculated by cooking 2 grams of grains with 20 ml of distilled water. The grains were then placed in a 100 ml beaker with water and allowed to heat in an electric heater. After the grains were cooked, they were removed. It was calculated using the formula below [14].

$$\text{Water uptake ratio}\,(\%) = \frac{\text{Weight of cooked grains}}{\text{Weight of uncooked grains}} \times 100$$

2.5.3 Elongation Ratio (mm)

The average length of the uncooked *V.aconitifolia* grains was recorded. Then, 2g of V. aconitifolia grains were taken in a beaker with 20 ml of distilled water and cooked using an electric heater. When the grains reached their optimum cooking time, they were taken to measure the length of the grain. The elongation ratio was calculated using the formula below[14].

$$\text{Elongation ratio (mm)} = \frac{\text{Legthofthe cooked grains}}{\text{length of the uncooked grains}}$$

2.5.4 Alkali Spreading Value

V.aconitifolia (10 seeds) were taken and placed with individual spacing in a petri dish with 1.7% Potassium Hydroxide solution (10 ml). The petri dish was then placed in an incubator at a temperature of 27.8 °C for 24 hours. The value of the spreading of each grain was measured by a 7-point numerical scale [22].

2.5.5 Swelling Power (%)

Swelling power was determined by the Reference of Malomo et al. [22-27]. 40 ml of distilled water was added to a 50 ml centrifuge tube, along with 1 gram of ungerminated and germinated V. aconitifolia flour, and the volume was denoted in ml/grams. The divergence in positioning of starch and amylase within the granules influences the capacity for swelling and solubility [27].

2.6 Statistical Analysis

The data were analyzed using descriptive statistics to summarize the physical and functional properties of *V.aconitifolia.* The mean and standard deviation (SD) were calculated for each parameter. The experiment was conducted in triplicate (n = 3). The data were presented in tables to provide a clear overview of the results. All statistical analyses were conducted using SPSS version 20.

3. Results and Discussion

3. 1 Standardization of Germination

Table 1. Growth of the sprout with different colours based on hours

Variation	Germination Hours	Colour intensity
I	12	High
II	24	High
III	36	Medium
IV	48	Low

The changes in color intensity of the sprout over time (Table 1) can be attributed to physiological changes during germination. Initially, the high color intensity observed at 12 and 24 hours may be due to the breakdown of seed dormancy and the initiation of germination, characterized by enzyme activation and the mobilization of stored nutrients. As germination progresses, the seedling's reliance on stored nutrients decreases, transitioning to a photosynthesis-based food production system. This shift may be reflected in the decrease in color intensity from medium to low between 36 and 48 hours.

The decrease in color intensity over time may also be related to pigment degradation, such as anthocyanins responsible for initial sprout coloration [28]. As the seedling grows, new pigment production (e.g., chlorophyll) may contribute to changes in color intensity. This is consistent with studies showing that chlorophyll biosynthesis and photosynthesis increase during germination [29]. Additionally, physiological and biochemical changes during germination, such as the breakdown of stored nutrients and the activation of enzymes, can also influence seedling coloration.

3.2 Physicochemical Characterization of Ungerminated and Germinated *V.aconitifolia*

The physical properties like legume length, breadth, thousand kernel weight, equivalent diameter, and sphericity of *V.aconitifolia* are presented in Table .2.

Table 2. Physical characterization of *V.aconitifolia* legume

S. No.	Physical Properties	Ungerminated *V.aconitifolia* legume	Germinated *V.aconitifolia* legume
1.	Thousand Legume weight (g)	4.00±0.23	6±0.22
2.	Thousand kernel volume (ml)	3.6±0.16	5.4±0.27
3.	Legume length(cm)	0.46±0.02	0.57±0.03
4.	Legume breadth (cm)	0.3±0.01	0.6±0.01
5.	Thickness (cm)	0.47±0.02	0.52±0.03
6.	Equivalent diameter(cm)	0.0135±0.001	0.0148±0.001
7.	Sphericity (cm)	0.03±0.001	0.05±0.002
8.	Density (mm)	1.1±0.01	1.6±0.02

The physical properties of *V.aconitifolia* legume were significantly affected by germination. The thousand-legume weight and thousand kernel volume increased by 50% and 50%, respectively, after germination. This increase in weight and volume is consistent with previous studies, which reported that germination can improve the physical properties of legumes [3-4]. The legume length, breadth, and thickness also increased after germination, indicating an overall increase in size. The equivalent diameter and sphericity of the legume increased slightly from 0.03 to 0.05 after germination, indicating a minor change in shape.

These results are in agreement with a recent study, which reported that germination can improve the physical properties of legumes, including size, shape, and texture [14].

The density of the legume also increased after germination, indicating an improvement in compactness. This result is consistent with previous studies, which reported that germination can improve the density of legumes [3-4]. Overall, the results suggest that germination can significantly improve the physical properties of *V.aconitifolia* legume, making it a more desirable ingredient for food applications.

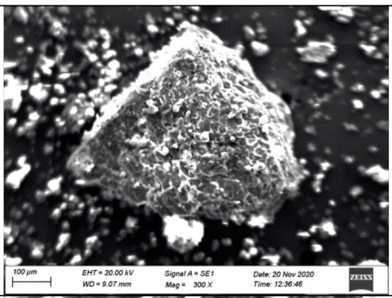
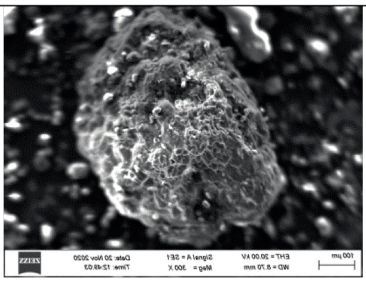
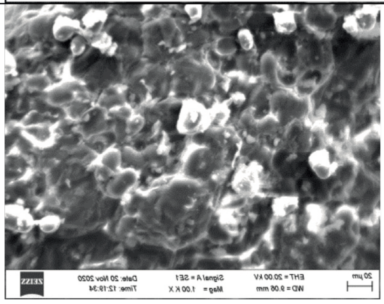
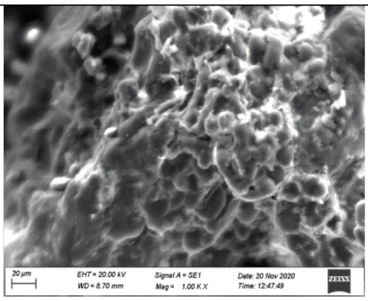
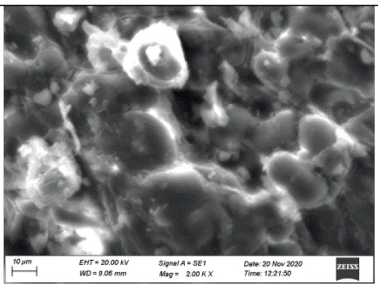
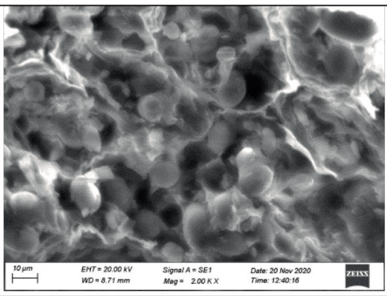
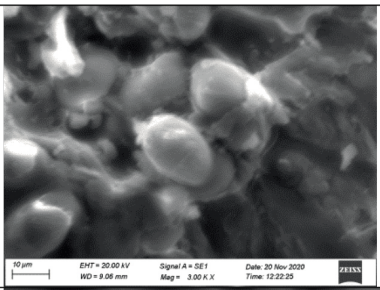
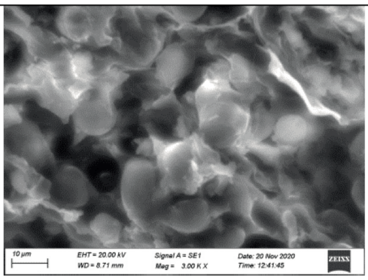
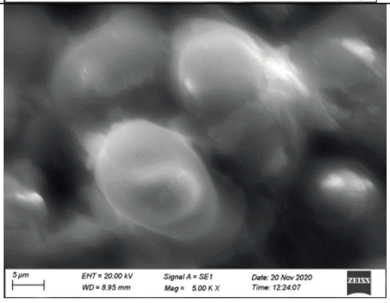
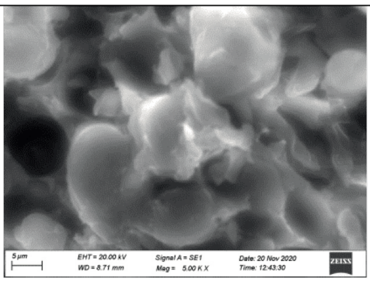
Table 3. Physical characterization - Bulk Density, True Density, and Porosity

S.No.	Physical Characterization	Ungerminated *V.aconitifolia*flour (g)	Germinated *V.aconitifolia*flour(g)
1.	Bulk density (ml)	0.783 ± 0.02	0.691 ± 0.02
2.	True Density (ml)	1.349 ± 0.01	1.234 ± 0.01
3.	Porosity (%)	41.76 ± 2.66	44.31 ± 2.04

The physical characterization (Table 3) of *V.aconitifolia* flour revealed interesting results. The bulk density and true density values were found to be similar, indicating minimal porosity or void space between the particles. This suggests that the germination process may not have significantly altered the physical structure of the *V.aconitifolia* flour. The similar density values could be attributed to the dense packing of particles, which may not have been affected by the germination process.

The porosity of ungerminated *V.aconitifolia* flour was 41.76%, which increased to 44.31% after germination. This increase in porosity can be attributed to the breakdown of complex cellular structures and the activation of enzymes during the germination process. Specifically, the enzymes α-amylase, β-amylase, and proteases are activated, breaking down starches and proteins into simpler molecules [4]. This breakdown creates more spaces within the flour, leading to increased porosity. Furthermore, the germination process also involves the degradation of phytic acid, a compound that can inhibit enzyme activity and bind minerals [3]. The reduction of phytic acid during germination can contribute to the increased porosity and improved nutritional availability of the flour. Overall, the results suggest that germination can improve the physical properties of *V.aconitifolia* flour, making it a more desirable ingredient for food applications."

Table 4. Scanning Electron Microscopy (SEM) Analysis of Ungerminated and Germinated *V.aconitifolia* Flour

S. No	**Particulars**		***V.aconitifolia* Flour**	**Germinated *V.aconitifolia* Flour**
	Magnitude (X)	**Range (µm)**		
1.	300	100		
2.	1000	20		
3.	2000	10		
4.	3000	10		
5.	5000	5		

The SEM micrographs of *V.aconitifolia* flour and germinated *V.aconitifolia* flour (Table 4) revealed distinct topographical features, underscoring the impact of germination on the physical properties of the flour. The images, captured at various magnifications, showcased a range of surface morphologies, including triangular, elliptical, pipe arch, and oval shapes, which were more pronounced in the germinated sample.

The SEM analysis revealed a soft and smooth surface texture for both ungerminated and germinated *V.aconitifolia* flour, with no visible pores. This observation is consistent with previous studies, which reported similar surface characteristics in moth bean granules [30]. Furthermore, the SEM images revealed the presence of both small and large starch granules in both ungerminated and germinated *V.aconitifolia* flour, with shapes ranging from cylindrical to oval and elliptical. This finding is corroborated by the high starch content reported in *V.aconitifolia*[4].

The germinated sample exhibited a more heterogeneous surface morphology, with a greater presence of irregularly shaped starch granules. The SEM analysis revealed changes in the starch granule structure of *V.aconitifolia* flour after germination, suggesting potential alterations in its functional properties. During germination, the activity of enzymes such as amylase and protease can lead to the partial degradation of starch granule structures, resulting in changes to the molecular structure and breakdown of starch. These changes may impact the flour's texture, solubility, and digestibility. Further research is needed to fully understand the effects of germination on starch breakdown and molecular structural changes in *V. aconitifolia* flour.

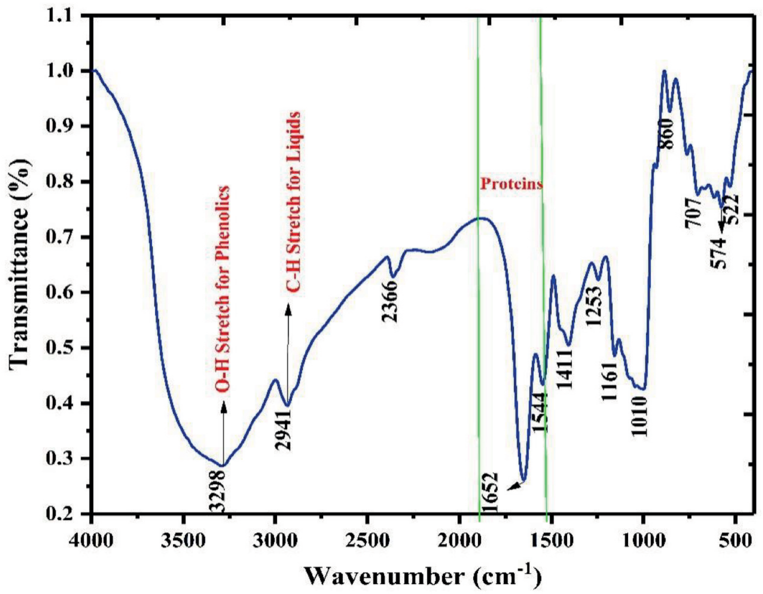


Figure 1. Graphical Representation of Fourier Transform Infrared (FT-IR) Spectra of ungerminated *V.aconitifolia*

The FTIR spectral imaging comparison between ungerminated and germinated *V.aconitifolia* flour reveals significant biochemical differences associated with germination. FTIR absorbance intensity at various wave numbers is indicative of the concentration of biomolecular functional groups such as proteins, lipids, and phenolic compounds.

Fourier Transform Infrared (FTIR) spectroscopy was employed to investigate germination-induced alterations in the molecular composition of *V.aconitifolia* flour. Comparison between ungerminated (S1) and germinated (S2) samples revealed significant changes in the infrared absorption patterns, particularly in regions corresponding to key biomolecules. The germinated sample exhibited higher mean absorbance intensity (3.47) compared to the ungerminated one (4), indicating an increased presence of functional groups associated with bioactive and nutritional compounds. This molecular enrichment is consistent with the activation of enzymatic and metabolic pathways during germination, leading to hydrolysis of macromolecules and synthesis of simpler, more bioavailable compounds [31].

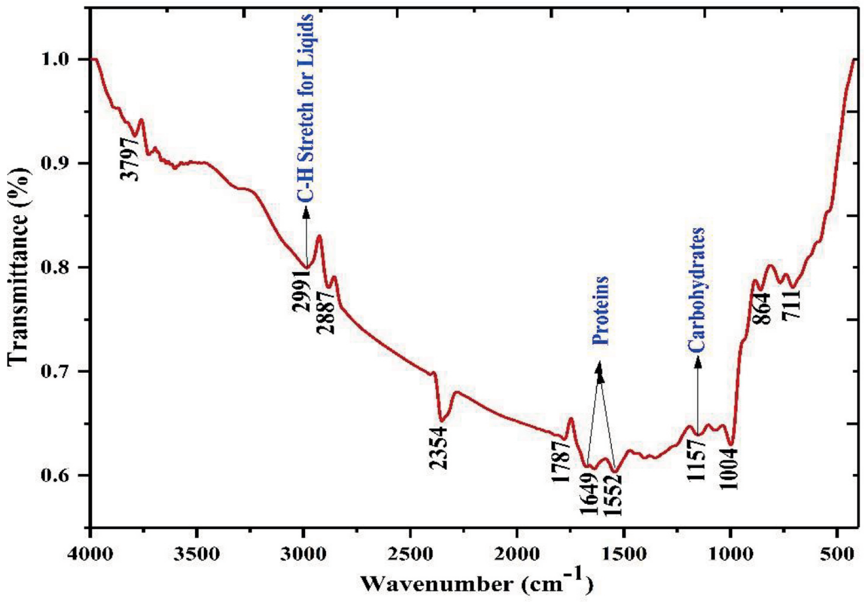


Figure 2 Graphical Representation of Fourier Transform Infrared (FT-IR) Spectra of germinated *V.aconitifolia*

Characteristic absorption bands observed near ~3300 cm^{-1} (O–H stretch) were more prominent in the germinated sample, signifying an increase in hydroxyl-containing compounds, such as phenolics and carbohydrates. These compounds contribute to enhanced antioxidant activity and improved physicochemical functionality. Likewise, the elevated peak intensity around ~2940 cm^{-1}, attributed to C–H stretching in lipids, suggests changes in lipid profiles, possibly through lipid mobilization or remodeling during germination. The bands observed at ~1650 cm^{-1} and ~1540 cm^{-1} correspond to amide I and II regions respectively, and their increased intensity in the germinated flour points to elevated protein levels or conformational changes in existing proteins—alterations that are closely linked with improved dough-forming ability, water absorption, and textural properties relevant to cooking performance.

These structural changes, highlighted by FTIR imaging, support the observed enhancements in the functional and cooking properties of the germinated flour. Improved solubility, emulsifying activity, and thermal behavior, as documented in similar studies, can be attributed to these biochemical transformations [32]. The molecular insights from FTIR spectroscopy thus reinforce the potential of germination as a natural and effective method to enhance the physicochemical and functional value of *V.aconitifolia* flour for use in nutritionally enriched food formulations.

3.3 Functional Properties of Ungerminated and Germinated *V.aconitifolia*

The functional properties (Table 5) of *V.aconitifolia* flour were significantly affected by germination. The water absorption capacity (WAC) of germinated *V.aconitifolia* flour was significantly higher (21 ± 1.65%) compared to ungerminated flour (18 ± 1.66%). This increase in WAC can be attributed to the structural changes in starch granules upon germination. Specifically, the activation of enzymes such as amylase during germination can lead to the disruption of starch granules, increasing the availability of hydrophilic groups, such as hydroxyl and amino groups, on the surface of the starch granules [4]. Additionally, the breakdown of starch molecules into simpler sugars can also contribute to the increased water absorption capacity. These changes in starch structure and composition can enhance the hydrophilic properties of the flour, leading to improved water absorption capacity

Table 5. Functional Properties

S.No.	Functional Properties	Ungerminated *V.aconitifolia*	Germinated *V.aconitifolia*
1.	Water Absorption Capacity (%)	18 ± 1.66	21 ± 1.65
2.	Oil Absorption Capacity (%)	23 ± 1.95	15.62 ± 1.20
3.	Foaming capacity (%)	25 ± 2.05	28 ± 1.85
4.	Emulsification capacity (%)	10.5 ± 0.95	13 ± 1.06
5.	Water solubility index (%)	71.17 ± 4.66	82 ± 4.44

In contrast, the oil absorption capacity (OAC) of germinated *V.aconitifolia* flour was lower (15.62 ± 1.20%) compared to ungerminated flour (23 ± 1.95%). This decrease in OAC can be attributed to the increased availability of hydrophilic groups on the surface of the starch granules after germination, which reduces the ability of the flour to absorb oil [14]. The foaming capacity (FC) of germinated *V.aconitifolia* flour was higher (28 ± 1.85%) compared to ungerminated flour (25 ± 2.05%).

This increase in FC can be attributed to the increased availability of proteins and other surface-active compounds after germination, which enhances the ability of the flour to form and stabilize foams [3]. The emulsification capacity (EC) of germinated *V.aconitifolia* flour was higher (13 ± 1.06%) compared to ungerminated flour (10.5 ± 0.95%). This increase in EC can be attributed to the increased availability of proteins and other surface-active compounds after germination, which enhances the ability of the flour to form and stabilize emulsions [4].

The water solubility index (WSI) of germinated *V.aconitifolia* flour was significantly higher (82 ± 4.44%) compared to ungerminated flour (71.17 ± 4.66%). This increase in WSI can be attributed to the enhanced enzyme activity during germination, which leads to partial starch degradation. The breakdown of starch molecules into simpler sugars and the increased availability of hydrophilic groups on the surface of the starch granules contribute to improved water solubility [14]. Specifically, the activation of enzymes such as amylase during germination facilitates the hydrolysis of starch molecules, resulting in increased solubility and enhanced ability of the flour to dissolve in water.

3.4 Cooking properties of Ungerminated and Germinated *V.aconitifolia*

The cooking properties (**Table 6.**) of *V.aconitifolia* flour were significantly affected by germination. The optimum cooking time (OCT) of germinated *V.aconitifolia* flour was shorter (18 ± 1.40 minutes) compared to ungerminated flour (25 ± 1.90 minutes). The decrease in Optimum Cooking Time (OCT) can be attributed to the structural modifications of starch and proteins caused by enzymatic activity during germination. Specifically, enzymes such as amylase may partially hydrolyze starch, leading to a softer structure and a shorter cooking time. Additionally, the increased availability of hydrophilic groups on the surface of the starch granules after germination may also contribute to enhanced water absorption, further reducing the cooking time [4].

Table 6. Cooking properties

S.No.	Cooking Properties	Ungerminated *V.aconitifolia* flour	Germinated *V.aconitifolia* flour
1.	Optimum cooking time (min)	25 ± 1.90	18 ± 1.40
2.	Water uptake ratio (%)	18.5 ± 1.22	20 ± 1.82
3.	Elongation ratio(mm)	2.25 ± 0.15	2.95 ± 1.67
4.	Swelling Power (%)	15 ± 0.95	21 ± 1.35

The water uptake ratio (WUR) of germinated *V.aconitifolia* flour was higher (20 ± 1.82%) compared to ungerminated flour (18.5 ± 1.22%). This increase in WUR can be attributed to the increased availability of hydrophilic groups on the surface of the starch granules after germination, which enhances the ability of the flour to absorb water [14].

The elongation ratio (ER) of germinated *V.aconitifolia* flour was significantly higher (2.95 ± 1.67 mm) compared to ungerminated flour (2.25 ± 0.15 mm). This increase in ER can be attributed to the changes in protein structure and composition during germination, which in turn affect the starch structure. Specifically, the breakdown of protein-starch complexes and the increased availability of proteins and other surface-active compounds after germination can enhance the flexibility of the starch structure, leading to improved gel formation and stability [3]. A higher ER indicates better gel formation in starch, which can contribute to improved texture and structure in food products made from germinated *V.aconitifolia* flour.

The swelling power (SP) of germinated *V.aconitifolia* flour was higher (21 ± 1.35%) compared to ungerminated flour (15 ± 0.95%). This increase in SP can be attributed to the increased availability of hydrophilic groups on the surface of the starch granules after germination, which enhances the ability of the flour to absorb water and swell [4].

4. Conclusion

In conclusion, the present study investigated the effect of germination on the physical, functional, and cooking properties of *V.aconitifolia* flour. The results showed that germination significantly altered the physical properties of the flour, including bulk Density, true Density, and porosity. Specifically, germination led to a decrease in bulk density and true density, while increasing porosity. These changes can impact the functionality and cooking behavior of the flour.

The functional properties, such as water absorption capacity, foaming capacity, and emulsification capacity, were also enhanced after germination. Furthermore, the cooking properties, including optimum cooking time, water uptake ratio, elongation ratio, and swelling power, were improved after germination.

Overall, the study suggests that germination can be a useful technique to improve the physical, functional, and cooking properties of *V.aconitifolia* flour, making it a more desirable ingredient for food applications. The improved properties of germinated *V.aconitifolia* flour can be attributed to the increased availability of hydrophilic groups, proteins, and other surface-active compounds after germination.

The findings of this study have important implications for the food industry, as they suggest that germination can be a simple and effective way to improve the quality and functionality of legume flours. Further research is needed to explore the potential applications of germinated *V.aconitifolia* flour in specific food products, such as gluten-free baked goods, starch-based gel formulations, or functional snack foods, where its modified physical and functional properties can be leveraged to enhance nutritional value, texture, and overall product quality.

5. Acknowledgements

Author Contributions:

- Venipriyadharshini Loganathan - The sole author was responsible for the conceptualization, methodology, data collection, analysis and writing
- Kavitha – Supervision and final approval of the manuscript

Funding: This research received no external funding

Conflicts of Interest: The authors declare no conflict of interest

References

[1] Kumar, D.; Singh, M.; Kushwaha, M. Nutrient content, uptake and NUE of oats (2). *Indian Journal of Agronomy* **2021**, *66*, 466-473.

[2] National Nutrition Monitoring Board Report. *Government of India*. **2019**.

[3] Singh, R.; Kølvraa, S.; Bross, P.; Christensen, K.; Bathum, L.; Gregersen, N.; Tan, Q.; Rattan, S.I.S. Anti-inflammatory heat shock protein 70 genes are positively associated with human survival, *Current Pharmaceutical Design* **2010**, *16*(7), 796-801. https://doi.org/10.2174/138161210790883499

[4] Tomooka, N.; Senthil, N.; Pandiyan, M.; Ramamoorthi, N.; Kaga, A.; Vaughan, D.A. Collection and conservation of leguminous crops and their wild relatives in Tamil Nadu, India, *Annual Report on Exploration and Introduction of Plant Genetic Resources (NIAS, Tsukuba, Japan)* **2008**, *24*, 113-125.

[5] Tomooka, N.; Pandiyan, M.; Senthil, N.; Ramamoorthi, N.; Kaga, A.; Vaughan, D.A. Collection and conservation of leguminous crops and their wild relatives in Tamil Nadu, India, *Annual Report on Exploration and Introduction of Plant Genetic Resources (NIAS,Tsukuba, Japan)* **2009,** *25*, 83-109.

[6] Kumar, R.; Ghoshal, G.; Goyal, M. Biodegradable composite films/coatings of modified corn starch/gelatin for shelf life improvement of cucumber. *J Food Sci Technol.* **2021**, *58*(4), 1227-1237. https://doi.org/10.1007/s13197-020-04685-y

[7] Venipriyadharshini, L.; Kavitha, K. Moth Bean (Vigna aconitifolia) as Potential Supplement to Evaluate the Weight Gain in Wistar Albino Rats (Rattus norvegicus). *International Journal of Experimental Research and Review* **2023**, *36*, 127-134. https://doi.org/10.52756/ijerr.2023.v36.012

[8] González-Fonteboa, F.; Martínez-Abella, R.; Rodríguez-Álvaro, E.; Rey-Bouzón, S.; Seara-Paz, M.F. Herrador,3 - Use of coal bottom ash and other waste as fine aggregates in lightweight cement-based materials, *Woodhead Publishing* **2021**, 53-87. https://doi.org/10.1016/B978-0-12-820549-5.00026-7

[9] Zare, F.; Orsat, V.; Boye, J. Functional, Physical and Sensory Properties of Pulse Ingredients Incorporated into Orange and Apple Juice Beverages, *Journal of Food Research* **2015**, *4*, 5. https://doi.org/10.5539/jfr.v4n5p143

[10] Olika, E.; Abera, S.; Fikre, A. Physicochemical Properties and Effect of Processing Methods on Mineral Composition and Antinutritional Factors of Improved Chickpea *(CicerarietinumL.)* Varieties Grown in Ethiopia**,** *International Journal of Food Science* **2019,** 1-7. https://doi.org/10.1155/2019/9614570

[11] Kumar, R.; Ghoshal, G.; Goyal, M. Moth bean starch (Vignaaconitifolia): isolation, characterization, and development of edible/biodegradable films, *Journal of Food Science and Technology* **2019**, *56*(11), 4891-4900. https://doi.org/10.1007/s13197-019-03959-4

[12] Azeredo, HMC.; Waldron, KW. Crosslinking in polysaccharide and protein films and coatings for food contact–a review, *Trends Food Science Technology* **2016**, *52*, 109-122. https://doi.org/10.1016/j.tifs.2016.04.008

[13] Mohsenin, N.N. Physical properties of plant and animal materials. Vol. 1. Structure, physical characterisitics and mechanical properties **1970**, *1*, 734.

[14] Shreelalitha, S.J.; Sridhar, K.R. Physical and Cooking Properties of Seeds of Two Wild Legume Landraces of Sesbania, *International Journal of Agricultural Technology* **2018**, 14(3), 363-376.

[15] Ghasemi-Varnamkhasti, M.; Mobli, H.; Jafari, A.; Keyhani, A.R.; Hedori Soltanabadi, M.; Rafiee, S.; Kheiralipour, K. Some physical properties of rough rice (Oryza Sativa L.) grain. *Journal of Cereal Science* **2008**, 47, 496-501. https://doi.org/10.1016/j.jcs.2007.05.014

[16] Mijivoievic, M.; Zita, R.; Tania, P. Izmene ISTA rules changes in seed germination testing at the beginning of the 21st century, *Journal on Processing and Energy in Agriculture* **2018,** *22*(2), 40-45 https://doi.org/10.5937/JPEA1801040M

[17] Surender, M.; Sagare, D.; Setti, P. Durga, Ch.V.; FarzanaJabeen, Rani.; Sudarshan, M.R.; Sokka Reddy, S. Mean Performance of Normal and QPM Maize Genotypes forYield and Tryptophan Content, *International Journal of Current Microbiology and Applied Sciences* **2017**, *6*(11), 830-844. https://doi.org/10.20546/ijcmas.2017.611.098

[18] American Society of Agricultural Engineers. ASAE S352.2: Moisture Measurement-Unground grain and seeds. *In ASAE Standards* **2001,** 549-555.

[19] Matouk. Physical properties of legumes. *Journal of Food Science and Technology* **2018,** *55*(2), 533-539.

[20] Tosh, S.M.; Yada, S. Dietary fibres in pulse seeds and fractions: characterization, functional attributes and applications. *Food Research International* **2010**, *43*, 450-460. https://doi.org/10.1016/j.foodres.2009.09.005

[21] Flores, F.; Singh, J.; Kerr, W.L.; Parrish, D.; Shi, Y. Physical and chemical properties of sweet potato purees during processing. *Journal of Food Science* **2012**, *77*(4), S1448-S1455. https://doi.org/10.1111/j.1750-3841.2012.02672.x

[22] Evelyn, S.; Buckman, Ibok Oduro,Wisdom A. Plahar,Charles Tortoe, Determination of the chemical and functional properties of yam bean (*Pachyrhizuserosus* (L.) Urban) flour for food systems, *Food Science & Nutrition* **2017**, *6*(2), 457-463. https://doi.org/10.1002/fsn3.574

[23] Shuang-kui, D.; Hongxin, J.; Xiuzhu,Y.; Jay-lin, J. Physicochemical and functional properties of whole legume flour, *LWT-Food Science and Technology* **2014**, *55*(1), 308-313. https://doi.org/10.1016/j.lwt.2013.06.001

[24] Salma, H. A.; Nahid, A. A.; ElShazali, A. M.; Isam, Elfadil E. B. Changes in the functional properties as a function of NaCl concentration of legumes protein isolate by Trans glutaminase cross linking *International Food Research Journal* **2010**, *17*, 817-824.

[25] Adeleke, R.O.; Odedeji, J.O. Functional Properties of Wheat and Sweet Potato Flour Blends. *Pakistan Journal of Nutrition* **2010**, *9*, 535-538. http://dx.doi.org/10.3923/pjn.2010.535.538

[26] Ghumman, A.; Kaur, A.; Singh, N. Functionality and digestibility of albumins and globulins from lentil and horse gram and their effect on starch rheology, *Food Hydrocoll* **2016,** *61*, 843-850. https://doi.org/10.1016/j.foodhyd.2016.07.013

[27] Wani, IA.; Sogi, DS. Hamdani. Isolation, composition, and physicochemical properties of starch from legumes: a review. *Starch/Starke* **2016,** *68*, 834-845. https://doi.org/10.1002/star.201600007

[28] Zhang, Y.; Li, M.; Wang, X. Anthocyanins regulate seedling growth and development by modulating auxin signaling. *Plant Physiology* **2019**, *181*(2), 641-653. https://doi.org/10.1104/pp.19.00851

[29] Wang, X.; Li, Z.; Chen, G. Chlorophyll biosynthesis and photosynthesis in germinating rice seeds. *Journal of Plant Physiology*, **2020**, *247*, 153141. https://doi.org/10.1016/j.jplph.2020.153141

[30] Balakrishnan, P.; Sreekala, MS., Thomas, S. Morphology, transport characteristics and viscoelastic polymer chain confinement in nano composites based on thermoplastic potato starch and cellulose nano fibers from pineapple leaf. *CarbohydrPolym* **2017,** *169*, 176-188. https://doi.org/10.1016/j.carbpol.2017.04.017

[31] Chandrasekara, A.; Shahidi, F. Determination of antioxidant activity in free and hydrolyzed fractions of millet grains and characterization of their phenolic profiles by HPLC-DAD-ESI-MS^n. *Journal of Functional Foods* **2011**, *3*(3), 144-158. https://doi.org/10.1016/j.jff.2011.03.006

[32] Nkhata, S. G.; Ayua, E.; Kamau, E. H.; Shingiro, J. B. Fermentation and germination improve nutritional value and functionality of foods: A review. *Food Science & Nutrition* **2018,** *6*(8), 2449-2458. https://doi.org/10.1002/fsn3.846