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Green Pea–Soybean Tofu: Nutritional, Functional and Technological Perspectives – A Review

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Abstract

The increasing demand for nutritious, sustainable and diversified plant-based foods has stimulated interest in combining proteins from different legumes. Soybean is the conventional raw material for tofu because of its high protein content and favourable gel-forming properties. Green pea (*Pisum sativum* L.) is also a nutritionally valuable legume containing protein, dietary fibre, carbohydrates, minerals and bioactive compounds. Pea protein possesses useful functional properties such as water-holding, emulsification, foaming and gelation, although its gel strength and sensory characteristics may differ from those of soybean protein. Combining green pea with soybean may therefore provide an opportunity to develop a nutritionally improved and technologically acceptable tofu product while modifying the characteristic flavour, colour and texture of conventional tofu. This review examines the nutritional composition and protein characteristics of green peas and soybean, their functional and gelation properties, tofu processing technology, the role of coagulants, and the potential effects of pea–soybean blending on nutritional, physicochemical and sensory properties. Published evidence indicates that protein concentration, heating, pH, ionic strength, coagulant type and processing conditions are important determinants of protein gel formation and tofu quality. Studies comparing pea and soy proteins demonstrate differences in gel-forming behaviour, suggesting that blend ratio optimization is essential for obtaining desirable texture and water retention. The review identifies the potential of green pea–soybean tofu as an innovative plant-based protein food and highlights the need for further research on optimum blending ratio, coagulation conditions, nutritional composition, sensory acceptability, texture, yield and storage stability.

Keywords: Green pea, soybean, *Pisum sativum*, *Glycine max*, tofu, pea protein, soy protein, gelation, coagulant, plant-based protein.

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1. Introduction

Plant-based proteins have gained considerable attention because of increasing interest in sustainable food systems, nutritional quality and diversification of protein sources. Legumes are particularly valuable because they provide protein together with carbohydrates, dietary fibre, minerals and bioactive components. Pea and soybean are two important legumes that have been extensively investigated for their nutritional and functional properties.

Green pea (*Pisum sativum* L.) contains protein, starch, dietary fibre and several bioactive compounds. Reviews of pea composition indicate that peas contain approximately 20–25% protein on a dry basis, although composition varies according to cultivar, maturity and processing conditions. Pea proteins possess useful functional properties including solubility, water- and oil-holding capacity, emulsification, foaming and gelation.

Soybean (*Glycine max*) is the major raw material used for tofu production. Soybean proteins have favourable nutritional quality and excellent functionality for forming protein gels. During tofu manufacture, soybean proteins undergo structural changes due to soaking, grinding, heating and coagulation. The resulting protein network determines important characteristics such as tofu firmness, yield, water retention and sensory quality.

Although soybean is well established in tofu production, incorporation of another legume protein may provide opportunities to modify the nutritional and sensory characteristics of tofu. Green pea is a promising candidate because pea proteins have demonstrated gel-forming capacity and are increasingly used in plant-based foods.

A combination of green pea and soybean may therefore provide a complementary protein system. Soybean can provide the established tofu-forming matrix, while green pea can contribute its own nutritional components, colour and functional characteristics. However, the ratio of the two proteins needs careful optimization because pea and soy proteins do not behave identically during gel formation. A comparative study of pea and soy protein isolates showed that soy protein produced stronger gels under several tested conditions, whereas pea protein required higher concentration and still produced weaker gels.

Therefore, this review discusses the scientific basis and potential development of green pea–soybean tofu.

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2. GREEN PEA (*PISUM SATIVUM* L.)

Green pea is a leguminous vegetable belonging to the Fabaceae family. Peas are consumed in fresh, frozen, dried and processed forms. They are nutritionally important because they provide protein, carbohydrate, dietary fibre, vitamins, minerals and bioactive compounds.

A comprehensive review of pea reported that whole peas are rich in proteins, starches, dietary fibre and non-starch polysaccharides. Polyphenols, including flavonoids and phenolic acids, are also present, while phytic acid, lectins and trypsin inhibitors are among the antinutritional factors that may influence nutrient utilization. Processing methods such as soaking, drying, milling and cooking can modify the functional and nutritional characteristics of peas.

The protein fraction of pea is particularly relevant to tofu development. Pea protein contains mainly globulins and albumins, with legumin and vicilin representing important globulin fractions. Protein composition and processing conditions influence hydration, rheological behaviour and gelation.

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3. NUTRITIONAL IMPORTANCE OF SOYBEAN

Soybean is one of the most important protein-rich legumes used in human foods. Soybean provides protein, lipid, carbohydrates, minerals and bioactive compounds such as isoflavones.

Soy protein is considered nutritionally valuable because of its relatively favourable essential amino acid composition. A quantitative review of soy protein quality found generally high protein-quality scores among soy products, although values vary according to product type and processing conditions.

Soybean proteins are mainly represented by storage proteins such as glycinin and β-conglycinin. Their relative proportions influence the structure and quality of tofu. Research involving different soybean varieties has shown relationships between storage-protein composition and tofu hardness, yield and sensory quality.

4. Comparison of Pea and Soy Protein

Both pea and soybean are important plant protein sources, but their protein structures and functional properties differ.

Table 1. General comparison of pea and soybean proteins

Characteristic	Green pea	Soybean
Botanical name	*Pisum sativum* L.	*Glycine max*
Major protein fractions	Globulins and albumins	Glycinin and β-conglycinin
Protein functionality	Solubility, water holding, emulsification, foaming, gelation	Gelation, emulsification, water holding and heat-setting
Tofu relevance	Potential complementary protein	Established tofu protein
Gel strength	Generally weaker under some conditions	Generally stronger under conventional tofu conditions
Flavour consideration	Possible beany/pea flavour	Characteristic soy flavour
Main research opportunity	Blend optimization	Protein matrix for tofu

Pea protein reviews consistently identify gelation as an important functional property, while soybean protein has a long history of use in tofu because of its favourable gel-forming characteristics.

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5. Functional Properties of Pea Protein

Pea protein possesses several properties that are relevant to food product development.

5.1 Water-Holding Capacity

Water-holding capacity influences the moisture retention, yield and texture of protein-based products. In tofu, the ability of the protein network to retain water contributes to product softness, firmness and yield.

5.2 Emulsifying Properties

Pea proteins can interact with oil and water phases and therefore possess emulsifying properties. These characteristics have contributed to their use in beverages, dairy alternatives and other plant-based food systems.

5.3 Foaming Properties

Pea proteins can adsorb at air–water interfaces and form foams. Although foaming is less directly relevant to tofu, it demonstrates the surface activity of pea proteins.

5.4 Gelation

Gelation is particularly important for tofu development. Pea proteins undergo structural changes during heating and can form protein networks. However, the strength and stability of pea-protein gels depend on protein concentration, pH, ionic strength and processing conditions.

6. Functional Properties of Soy Protein

Soy protein has well-established functionality in food processing. Thermal treatment can cause protein unfolding, aggregation and network formation. These changes influence solubility, emulsification and gelation.

Recent reviews indicate that thermal processing can modify the conformation and intermolecular interactions of soy proteins and consequently improve or alter their gelation and other techno-functional properties.

In tofu production, the gel-forming ability of soybean protein is the fundamental principle responsible for curd formation. Therefore, soybean protein provides an important structural basis for a pea–soy tofu system.

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7. Pea–Soy Protein Interaction and Gelation

The combination of two plant proteins can result in interactions that differ from those observed in either protein alone. Protein concentration, pH, ionic strength and heating conditions influence intermolecular interactions and gel-network formation.

A study specifically investigating soy and pea protein gelation demonstrated that the two proteins have different gelation requirements. Strong soy-protein hydrogels were obtained under conditions where pea protein produced weaker gels, showing that protein type significantly influences gel behaviour.

This finding is important for green pea–soybean tofu. If a proportion of soybean protein is replaced with pea protein, the final gel may change in firmness, water retention and elasticity. Increasing pea proportion may introduce nutritional and sensory advantages but may also reduce gel strength if the pea protein concentration and coagulation conditions are not optimized.

Therefore, **pea:soy ratio is one of the most important formulation variables** for development of the product.

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8. Tofu: Principle and Processing

Tofu is a traditional soybean-based food produced by converting soybean milk into a protein gel. The basic process involves:

Soybean/pea selection → Cleaning → Soaking → Grinding → Filtration → Heating → Coagulation → Curd formation → Molding → Pressing → Tofu

Traditional tofu processing includes soaking and grinding of soybean, heating of the slurry, filtration and addition of a suitable coagulant. Raw material characteristics, heating conditions, coagulant type and concentration influence the final product.

For green pea–soybean tofu, the same general principle can be adapted, but processing conditions may need modification because green pea and soybean proteins differ in composition and gelation behaviour.

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9. Role of Heat Treatment

Heating is an essential step in tofu processing. Thermal treatment causes denaturation of proteins, exposing reactive groups and facilitating protein–protein interactions.

Soybean protein undergoes conformational changes during heating, followed by aggregation and network formation. Heat treatment can therefore influence the gel strength, water retention and texture of tofu.

In a pea–soy system, heat treatment must be sufficient to promote protein denaturation without causing excessive aggregation that could negatively affect dispersion or sensory quality.

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10. Role of Coagulants

Coagulants are essential for tofu formation. Traditional coagulants include calcium salts and magnesium salts, while acid and glucono-δ-lactone-based systems are also used.

Recent reviews classify tofu coagulants into salt, acid, enzyme and newer composite systems. Coagulant characteristics directly influence tofu texture, quality and physicochemical properties.

Table 2. Major coagulant categories relevant to tofu

Coagulant category	General action	Potential effect
Calcium salts	Ionic interaction and protein aggregation	Firm curd
Magnesium salts	Promotes protein aggregation	Firm/elastic texture
Acid coagulants	Lower pH and reduce protein solubility	Curd formation
GDL	Gradual acidification	Smooth and soft tofu
Composite systems	Combination of mechanisms	Adjustable texture

For pea–soy tofu, the optimum coagulant may differ from conventional soybean tofu. Therefore, coagulant type and concentration should be experimentally optimized.

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11. Effect of Pea:Soybean Ratio

The ratio of green pea to soybean is expected to influence both nutritional and technological characteristics.

A higher soybean proportion may provide stronger gel formation because soybean protein is well established in tofu manufacture. Increasing pea proportion may alter colour, flavour, protein composition and nutritional characteristics.

The optimum ratio should therefore balance:

- Protein content
- Gel strength
- Water retention
- Tofu yield
- Texture
- Colour
- Flavour
- Overall sensory acceptability

Suggested formulation concept for research

Formulation	Green pea	Soybean
F1	Low	High
F2	Moderate	Moderate
F3	High	Low

The exact percentages should be selected based on the experimental design rather than assuming a literature-derived optimum.

12. Nutritional Potential of Green Pea–Soybean Tofu

Combining pea and soybean may produce a nutritionally diversified plant-based food. Green peas contribute protein, dietary fibre, carbohydrates, minerals and bioactive compounds, while soybean contributes protein, lipids and isoflavones.

Soybean provides high-quality protein, while pea protein contributes a useful plant protein fraction and functional properties.

Nutritional evaluation of the final tofu should include:

- Moisture
- Total ash
- Protein
- Fat
- Carbohydrate
- Energy
- Dietary fibre, where applicable
- Calcium
- Iron
- Other selected minerals

The actual values must be obtained experimentally from the developed product rather than predicted from raw-material composition.

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13. Physicochemical Characteristics

The physicochemical characteristics of pea–soy tofu are expected to depend on formulation and processing conditions.

Important parameters include:

13.1 Moisture

Moisture influences texture, yield and storage stability.

13.2 Protein

Protein content reflects the contribution of both pea and soybean and is a key nutritional parameter.

13.3 pH

pH affects protein solubility, aggregation and coagulation.

13.4 Texture

Texture is one of the most important quality characteristics of tofu. Firmness is affected by protein composition, heating, coagulant type and pressing.

13.5 Yield

Tofu yield depends on protein extraction, protein concentration, coagulation efficiency and water retention.

13.6 Water-Holding Capacity

Water retention affects firmness, juiciness and structural stability.

Research on tofu consistently indicates that raw material properties and processing conditions can influence tofu quality.

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14. Sensory Evaluation

Sensory evaluation is essential when developing green pea–soybean tofu because the addition of pea may influence colour, aroma and flavour.

Important sensory attributes include:

- Appearance
- Colour
- Aroma
- Flavour
- Texture
- Mouthfeel
- Overall acceptability

Pea protein literature identifies characteristic beany flavour as one limitation in some food applications.

Therefore, the optimum pea:soy ratio should not be selected based only on nutritional composition. Consumer acceptance and sensory characteristics should also be considered.

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15. Advantages of Green Pea–Soybean Tofu

The combination may provide several potential advantages:

1. **Diversification of conventional tofu:** It introduces an alternative formulation to soybean-only tofu.
2. **Plant-based protein:** Both ingredients are plant protein sources.
3. **Nutritional diversity:** Pea contributes fibre and other nutrients, while soybean provides high-quality protein and isoflavones.
4. **Functional potential:** Both pea and soy proteins possess useful functional properties.
5. **Product innovation:** The formulation may be suitable for development of value-added legume foods.
6. **Research potential:** Different pea:soy ratios can be investigated for optimizing texture, nutrition and sensory quality.

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16. Limitations and Challenges

Despite its potential, several challenges should be considered.

16.1 Gel Strength

Pea protein may form weaker gels than soy protein under certain conditions. Therefore, replacing too much soybean may reduce tofu firmness.

16.2 Flavour

Pea proteins can have characteristic beany or grassy notes, which may influence sensory acceptance.

16.3 Colour

Green pea components may alter the colour of conventional tofu, potentially producing a greenish or cream-coloured product.

16.4 Processing Optimization

Conventional soybean tofu conditions cannot automatically be transferred to a pea–soy formulation because the proteins have different functional characteristics.

16.5 Coagulant Optimization

The type and concentration of coagulant must be optimized to obtain an acceptable balance between firmness and water retention.

17. Research Gap

A substantial body of research exists on pea protein functionality and conventional soybean tofu. Pea protein has been extensively reviewed for its nutritional and functional properties, while tofu research has established the importance of soybean protein, heating and coagulation.

However, **specific research on tofu developed using a green pea–soybean combination is comparatively limited**.

Important areas requiring further investigation include:

- Optimum green pea:soybean ratio.
- Protein extraction efficiency.
- Suitable pea and soybean milk concentration.
- Optimum heating conditions.
- Suitable coagulant and concentration.
- Effect of pH on gel formation.
- Pressing conditions.
- Nutritional composition.
- Physicochemical characteristics.
- Texture and water-holding capacity.
- Sensory acceptability.
- Storage stability.
- Microbiological quality.
- Consumer acceptance.

Therefore, systematic development and evaluation of green pea–soybean tofu can contribute useful information to the field of innovative plant-based food product development.

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18. Future Perspectives

Future research should focus on optimization of the pea:soybean ratio using experimental designs. Response surface methodology or other suitable statistical approaches may be used to investigate the combined effects of protein concentration, heating temperature, pH and coagulant concentration.

Further research could investigate protein interactions using rheological, microscopic and spectroscopic techniques. Such approaches may help explain how pea and soy proteins interact during gel formation.

Processing technologies such as controlled heating, high-pressure processing, ultrasound and enzymatic modification may also be investigated for improving protein functionality. Soy-protein processing research has demonstrated that thermal and emerging technologies can substantially modify protein structure and functionality.

Future studies should also consider nutritional quality, digestibility, sensory acceptance, shelf life and economic feasibility before commercial application.

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19. Conclusion

Green pea–soybean tofu represents a promising approach for developing an innovative plant-based protein food. Soybean provides the established protein matrix required for tofu formation, while green pea offers additional nutritional and functional characteristics.

Pea protein possesses water-holding, emulsifying, foaming and gelation properties, but its gel-forming behaviour differs from that of soybean protein. Research comparing pea and soy protein gels demonstrates that protein type, concentration, pH and ionic strength significantly influence gel formation.

The successful development of green pea–soybean tofu therefore depends on optimizing the pea:soybean ratio, protein concentration, heating conditions, coagulant type and concentration, pH and pressing conditions. Nutritional, physicochemical and sensory evaluation should be conducted to identify the most acceptable formulation.

Overall, green pea–soybean tofu has potential as a value-added legume-based food and provides an interesting research area for the development of nutritious and diversified plant-based protein products. However, further experimental studies are required to establish optimum formulation and processing conditions.

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