Pakistan Journal of Life and Social Sciences
www.pjlss.edu.pk

https://doi.org/10.57239/PJLSS-2026-24.1.0066

RESEARCH ARTICLE

Application of Hydrated Pea Protein Isolate In Meat Loaf Technology

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ARTICLE INFO

Received: MAY 25, 2026

Accepted: JUNE 20, 2026

Keywords

Pea protein isolate

Plant protein

Food technology

Formulation

Hydrated Module

Dosage

Meat products

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ABSTRACT

Background. Plant proteins, particularly legume proteins, possess pronounced emulsifying, water-binding, and gelling properties, making them promising ingredients for application in meat systems. Their use contributes to increased product yield, improved structural stability, and expanded formulation flexibility in meat processing technologies. This study investigates the feasibility of using hydrated pea protein isolate as a partial substitute for meat raw materials in meat loaf production. Meat bread samples were manufactured according to a standard formulation with partial replacement of beef by hydrated pea protein isolate (hydration ratio 1:3). The aim of the study was to evaluate the effect of meat raw material substitution level with hydrated pea protein isolate on the physicochemical and textural properties of meat bread. Materials and Methods. The study was conducted under laboratory conditions. First-grade beef and semi-fat pork were used as the main raw materials. Pea protein isolate in hydrated form (hydration ratio 1:3) was applied. Sensory evaluation was performed by a trained panel of ten assessors in accordance with GOST 9959–2015 “Meat and meat products. General conditions for sensory evaluation”. Cooking loss was determined as the percentage reduction in product mass after heat treatment. pH was measured according to GOST 26188-2016. Color characteristics were assessed using a spectrophotometer. Hardness and elasticity were determined using a texture analyzer “Structurometer ST-2”. Results. The incorporation of hydrated plant protein affected water and fat retention during thermal processing. At a substitution level of up to 15%, a reduction in cooking losses compared to the control sample was observed, indicating improved emulsion stability. Increasing the substitution level to 20–30% led to higher cooking losses, which can be attributed to weakening of the myofibrillar protein network and reduced water-holding capacity of the system.

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INTRODUCTION

The current strategy for the development of the meat industry is aimed at creating competitive next-generation products that combine high nutritional value, functionality, economic efficiency, and compliance with modern consumer requirements. Under conditions requiring the rational use of raw material resources, the implementation of resource-saving technologies and the expanded use of plant-based ingredients in meat product manufacturing have become particularly important (Shirokova et al., 2026; Tupol'skikh, et al., 2024).

One of the priority directions in the development of the industry is the use of plant protein ingredients that enable partial replacement of meat raw materials without compromising the quality of finished products. The application of plant-derived proteins contributes to increased product yield, improved water- and fat-binding capacity of meat systems, enhanced structural stability, optimization of production costs, and the development of products with targeted functional and technological properties (Kravchenko et al., 2020).

Hydrated pea protein isolates possess high emulsifying and water-binding capacities are of particular interest in meat product technology. The use of such ingredients improves the stability of meat emulsions, enhances the consistency and textural characteristics of finished products, and ensures quality stability during storage (Giro et al., 2021; Giro et al., 2022; Gorlov et al., 2025).

Meat loaf belongs to the category of emulsified meat products and represents a promising product for the implementation of innovative technological solutions. Owing to its formulation and processing characteristics, meat loaf allows the effective incorporation of combined protein systems, including plant-derived ingredients. The use of hydrated protein modules in meat loaf technology improves the functional and technological properties of meat batter, reduces thermal processing losses, and contributes to the formation of a stable product structure (Gorlov et al., 2024; Kuznetsova et al., 2020).

At present, the development of meat product technologies utilizing domestically produced plant raw materials is gaining increasing importance, in line with the import substitution strategy and the sustainable development of the food industry (Sentkowska and Pyrzyńska, 2023). The incorporation of plant-based ingredients not only enhances the efficiency of meat raw material utilization but also expands the range of functional food products (Thiruvengadam et al., 2024; Cabuk et al., 2018; Chao and Aluko, 2018; Eckert et al., 2019).

The aim of this study was to evaluate the effect of replacing meat raw materials with hydrated pea protein isolate on the physicochemical and textural properties of meat loaf.

MATERIALS AND METHODS

The study was conducted using meat loaf samples produced using a hydrated protein module. Sensory evaluation was performed by a trained panel of ten assessors in accordance with GOST 9959–2015, “Meat and Meat Products. General Requirements for Sensory Evaluation.” Cooking losses were determined as the percentage reduction in product weight after thermal processing. The pH value was measured according to GOST 26188–2016. Color characteristics were assessed using a spectrophotometer. Hardness and elasticity were determined using a Structurometer ST-2 texture analyzer. Meat loaf samples were prepared according to the formulations shown in Table 1.

Table 1: Formulations of the Control and Experimental Samples

Name of meat raw materials, food ingredients, and additives	Control	Samples			
		No 1	No2	No3	No4
Raw materials, kg per 100 kg of unsalted raw material					
First-gradebeef	40	20	30	20	10
Semi-fatpork	60	60	60	60	60
Hydratedpeaproteinisolate	–	20	10	20	30
Food ingredients and additives, g per 100 kg of meat raw materials					
Curingmixture (0.6% nitrite)	1400	1400	1400	1400	1400
Salt	300	300	300	300	300
Granulatedsugar	150	150	150	150	150
Food-gradephosphates	300	300	300	300	300
Sodiumascorbate	50	50	50	50	50
Water/ice, kg	35	35	35	35	35

Each sample weighed 2.5 kg. First-grade beef and semi-fat pork were used as the primary raw materials.

In the experimental samples, a portion of the beef was replaced with hydrated pea protein isolate. The hydration ratio was 1:3. The meat raw materials were ground through a 2–3 mm plate and subsequently emulsified in a bowl cutter with the addition of the hydrated protein isolate, water, salt, and other ingredients until a homogeneous meat batter was obtained.

The batter was filled into metal meat loaf moulds. Thermal processing was carried out at 78°C until the core temperature reached 72 ± 2°C. After cooling, the samples were evaluated for sensory, physicochemical, and textural properties.

RESULTS AND DISCUSSION

Figure 1 presents the cooking losses of meat loaf samples during thermal processing. Analysis of the data showed that the incorporation of hydrated pea protein isolate into the formulation affected the ability of the meat system to retain moisture and fat during heating.

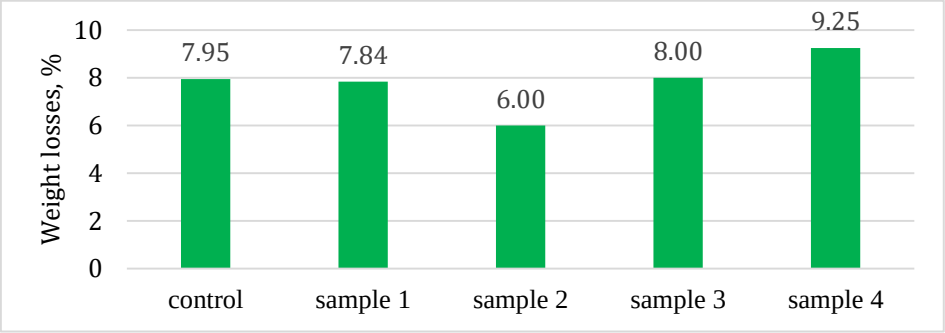

Figure 1: Cooking losses of meat loaf samples during thermal processing

The incorporation of hydrated pea protein isolate at levels of up to 20% as a replacement for meat raw materials did not result in a substantial increase in cooking losses compared with the control sample. These findings indicate the high water-holding capacity of the isolate and its ability to stabilize the meat emulsion during thermal processing. This effect is likely associated with the pronounced hydrophilic properties of the protein component, which facilitate the binding of free water and the retention of the fat phase within the product structure.

The lowest cooking losses were observed in the sample containing 15% hydrated pea protein isolate. This effect may be attributed to the formation of a more stable protein–fat emulsion system, in which an optimal ratio of meat and plant proteins was achieved. At this inclusion level, effective interactions between proteins and water contributed to increased density and stability of the meat batter structure.

However, further increases in the level of hydrated pea protein isolate were accompanied by a tendency toward higher cooking losses during thermal processing. This may be associated with partial weakening of the meat emulsion structure due to excessive replacement of meat proteins with plant-derived components.

The reduction in the content of myofibrillar proteins involved in the formation of a stable heat-induced protein network likely resulted in decreased water retention during heating.

The results of color measurements (Fig. 2) showed that increasing the level of hydrated pea protein isolate altered the color characteristics of the meat loaf samples.

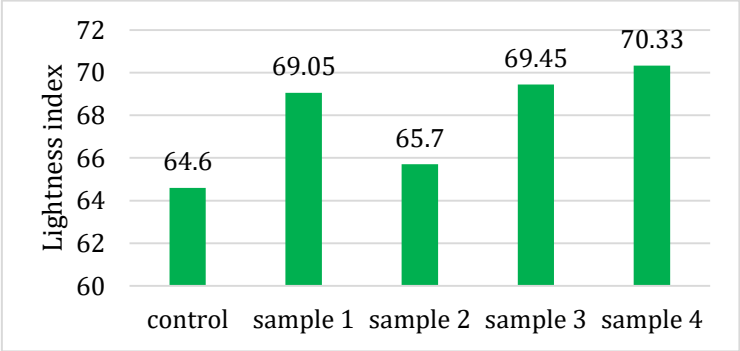

Figure 2: Lightness (L*) of meat loaf samples

The experimental samples exhibited higher lightness values and a simultaneous reduction in redness intensity. This trend can be attributed to the reduced proportion of meat raw materials in the formulation and, consequently, the lower content of heme pigments, primarily myoglobin, which is responsible for the characteristic color of meat products. The increase in lightness may also be attributed to the intrinsic propertiesof hydrated pea protein isolate, which has a lighter color than meat raw materials. The incorporation of the plant protein ingredient resulted in visible lightening of the meat batter, particularly at higher levels of meat substitution.

The decrease in redness values (Fig. 3) with increasing levels of pea protein isolate indicates a reduction in the intensity of color-forming processes characteristic of meat systems. Nevertheless, samples containing up to 20% hydrated pea protein isolate retained acceptable sensory characteristics and showed no pronounced deviations in appearance. However, further increases in the level of incorporation resulted in more noticeable color changes, which may have negatively affected consumer perception of the finished product.

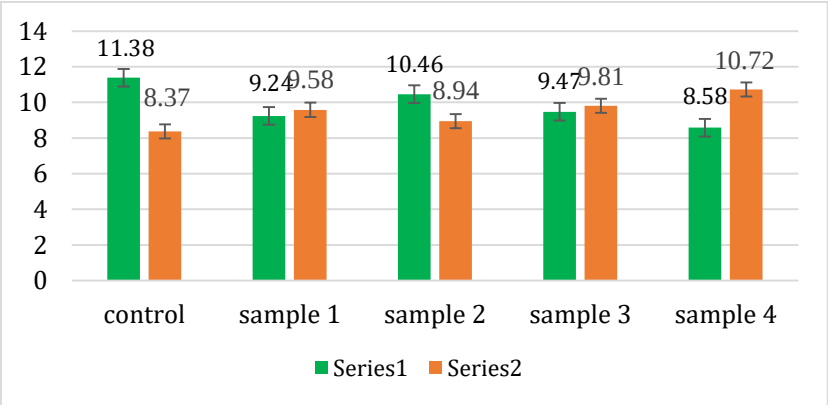

Figure 3: Redness (a*) and yellowness (b*) values of meat loaf samples (Series 1 – redness; Series 2 – yellowness)

Table 2 presents the results of pH and water activity measurements for the meat loaf samples.

Table 2: pH and water activity of meat loaf samples

Samples	pH	Water activity (aw)
Control	6.43±0.02	0.9811±0.0001
Sample 1	6.39±0.02	0.9822±0.0001
Sample 2	6.46±0.01	0.9816±0.0001
Sample 3	6.37±0.02	0.9824±0.0001
Sample 4	6.46±0.01	0.9822±0.0001

Statistical analysis showed that the differences in pH values between the experimental and control samples were not statistically significant ($p > 0.05$), indicating that the incorporation of hydrated pea protein isolate did not affect the pH characteristics of the meat system. The addition of hydrated pea protein isolate contributed to reduced hardness and the development of a more tender texture. At inclusion levels of up to 20%, the textural properties remained comparable to those of the control sample.

Sensory evaluation demonstrated that samples containing up to 10% hydrated pea protein isolate were comparable to the control sample in terms of flavour, aroma, and texture. At an inclusion level of 20%, a slight plant-derived aftertaste was detected.

CONCLUSIONS

1. The results of this comprehensive study demonstrated that the use of hydrated pea protein isolate in meat loaf production is a technologically feasible and promising approach for improving meat product formulations. The findings indicate that incorporation of hydrated pea protein isolate at levels of up to 10% allows the production of high-quality products without significant deterioration of sensory, physicochemical, or textural properties.

2. At this inclusion level, the experimental samples retained the characteristic flavor, aroma, color, and texture of meat loaf. The products exhibited a dense, homogeneous, and elastic structure without evidence of fat and moisture separationor emulsion breakdown. These findings

indicate that hydrated pea protein isolate can effectively contribute to the formation of a stable protein–fat system, ensuring moisture and fat retention during thermal processing.

3. Analysis of physicochemical parameters showed that the incorporation of hydrated pea protein isolate at levels of up to 10% did not result in substantial changes in water activity or pH. The stability of these parameters is of considerable technological importance, as water activity directly affects microbiological stability and shelf life, whereas pH influences the functional properties of meat proteins, including water-holding capacity and product texture.

4. Increasing the level of hydrated pea protein isolate to 20% also did not result in substantial changes in the textural characteristics of the product. The experimental samples maintained satisfactory hardness, elasticity, and structural integrity. This indicates the high functional and technological potential of the protein ingredient, including its hydration, emulsifying, and stabilizing properties.

5. The findings confirm that the use of hydrated pea protein isolate is consistent with current trends in the meat industry aimed at the rational utilization of raw materials, the development of resource-efficient technologies, and the expanded use of plant-based ingredients in meat product manufacturing.

6. The incorporation of hydrated pea protein isolate not only improves the functional and technological properties of meat systems but also contributes to increased product yield, reduced processing losses during thermal treatment, and optimization of production costs. Furthermore, the use of such ingredients creates opportunities for the development of novel combined meat products with enhanced consumer characteristics and improved nutritional value.

7. The application of hydrated pea protein isolate in meat loaf technology represents a promising approach for expanding and improving the range of meat products and may be considered an effective tool for increasing both technological and economic efficiency in meat processing.

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